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A Framework of Distinct Musical Chills: Theoretical, Causal, and Conceptual Evidence

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Submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in the Department of Music

Durham University, September 2019

ABSTRACT

The phenomenon of musical chills has attracted extensive attention in previous music and emotion research, correlating the experience with musical structure, psychoacoustics parameters, individual differences in listeners, and the listening situation. However, there are three crucial limitations in the literature: 1) The emotional characteristics of musical chills have not been explored, and are poorly understood; 2) musical chills have never been causally manipulated, and no theories have been tested; and 3) it is unclear whether chills are a unified psychological construct, or a set of distinct experiences, distinguished at the levels of subjective feeling, psychophysiological response, individual differences, and underlying psychological induction mechanisms. Across five studies, ranging from qualitative surveys to experimental manipulations of musical chills, these limitations were addressed in the current thesis, with results suggesting firstly that musical chills are often mixed emotional experiences, described as moving, bittersweet and intense; secondly, that musical chills can be manipulated, and corresponding theories tested, with a novel experimental paradigm, by removing key sections in a piece or changing psychoacoustic parameters such as loudness and brightness; finally, that there are likely distinct types of chills experiences, which across multimedia are linked to both the affective dimension of valence and individual differences such as trait empathy, and with music through mechanisms of fear and vigilance on the one hand, and social bonding on the other. The studies and results are discussed in terms of two categories of musical chills experiences, culminating in a preliminary *Distinct Musical Chills Framework*, producing a series of testable hypotheses for future empirical work, and a comprehensive research agenda for the field moving forward.

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List of Publications

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1. Introduction

Music occupies a privileged position as a phenomenon of human action and activity (Molnar-Szakacs & Overy, 2006) that is ubiquitous across all known cultures and histories (Peretz, 2006), and, particularly in Western cultures, serves as a prominent object for aesthetic engagements and enjoyment (Brattico & Pearce, 2013; Greasley & Lamont, 2011; North, Hargreaves & Hargreaves, 2004). The commercial music industry strongly competes with other large industries of human entertainment, such as film, television, theatre and video games. Presently, music remains not only ubiquitous across cultures, but also across environments, activities, and times within a given culture (Burnett, 2002); an example of this is the prevalent sonic branding utilisation of music, with almost any store or commercial environment being supported and augmented by background music (Gustafsson, 2015; North & Hargreaves, 1997). Furthermore, with the advent of portable music playback technology, and more recently the development of streaming services that has transformed the music consumption and production process, music has become a powerful tool for everyday life, in that different kinds of music are accessible portably to accompany household tasks or chores, travel and transportation, studying or working, and to aid or enhance activities such as exercise or sports (Greasley & Lamont, 2011; Krause, North & Hewitt, 2015; Laukka & Quick, 2013).

These reported functions and uses of music in modern times mirror psychological work that has long attempted to identify and explain the processes and abilities of listeners to make sense of the music being heard. Research on perception has assessed the process of musical understanding and listening, from the perception of tonal hierarchies and stability in music (Krumhansl & Kessler, 1982), perceptions of musical tension (Bigand, Parncutt & Lerdahl, 1996; Lehne & Koelsch, 2015), and processing of music cross-modally (Vines, Krumhansl, Wanderley & Levitin, 2006), to auditory illusions such as the tritone paradox (Deustch, 1991). Cognitive approaches to music are also prevalent, assessing for example how accurate pitch memory is across listeners (Halpern & Müllensiefen, 2008; Heaton, 2003; Zatorre, Evans & Meyer, 1994), whether listeners can perceive large-scale musical form (Granot & Jacoby, 2011), and how listeners may process and understand ambiguous musical rhythms (Phillips-Silver & Trainor, 2005). These are substantial lines of enquiry in the field of music psychology, but crucially, when considering the cultural importance of music alongside motivations for engaging with music, an essential component of musical experience is emotion.

1.1 Music and Emotion

The field of music and emotion has recently blossomed into a highly active area of research within the broader context of music psychology, evidenced by numerous contributions on the topic in a recent music psychology handbook (Hallam, Cross & Thaut, 2016), and two handbooks focussed specifically on music and emotion (Juslin & Sloboda, 2001; 2010a). One of the commonly reported, central motivations for listening to music in everyday life is to experience emotions and to regulate mood or broader affective states (Saarikallio & Erkkilä, 2007; Saarikallio, Maksimainen & Randall, 2018); some of these experiences may be notably intense (Gabrielsson & Wik, 2003), with long-lasting consequences for life and wellbeing (Schäfer, Smukalla & Oelker, 2014). The emotional capacity of music is complicated, particularly across different theoretical perspectives on emotion (Gross & Barrett, 2011), and has few immediate explanations; for example, if emotions are conceptualised as adaptively important responses to external events, then it is unclear how music may elicit such a response, given that music carries no immediately obvious adaptive value (Huron, 2001), especially in comparison to more basic needs (Maslow, 1943). This complexity has attracted a great deal of researchers across disciplines such as social psychology, evolutionary psychology, neurology, philosophy and emotion science. Importantly, understanding the relationship between music and emotion has a substantial level of potential for elucidating holistic debates, discussions and theories regarding the nature and facets of emotion more broadly.

The experience of emotions with music is the broader focus of the current research project. However, one approach to developing an understanding at this holistic level is to investigate a specific, emotional phenomenon in relation to music; crucially, there is one such phenomenon which has often been described as *musical chills*. Whilst chills will be fully addressed in **Chapter 3** of the current project, it is pertinent to state here that the response is often conceptualised as an intense emotional experience accompanied by goosebumps, shivers down the spine, and more subjective tingling sensations. This experience has received notable attention in music and emotion research, yet it is poorly understood: It is unknown as to how listeners describe musical chills, in terms of emotional qualities and characteristics; furthermore, existing work linking chills to certain musical features has exclusively been correlational in design, meaning no explanation or theory of the response has ever been causally assessed; finally, as a result of the previous two limitations, it is not clear as to whether chills refer to a unified psychological construct, or whether chills describe a set of distinct experiences, distinguished by virtue of phenomenology, psychophysiology, elicitors and psychological processes implicated. These central issues in musical chills research reflect broader limitations in the music and emotion literature; a wide variety of emotional models and data collection methods have been used (Eerola & Vuoskoski, 2011; 2013; Eerola, Vuoskoski, Peltola, Putkinen & Schäfer, 2018; Juslin & Laukka, 2004; Swaminathan & Schellenberg, 2015), meaning that how listeners understand and conceptualise their emotional experiences with music has yet to be consistently clarified; relatedly, numerous underlying processes and mechanisms of musical emotion have been proposed (Scherer & Coutinho, 2013; Juslin & Västfjäll, 2008), yet rarely have they been empirically tested; and finally, just as musical chills may not always be comparable experiences, so too is there a wider debate regarding whether musical emotions are distinguishable from 'everyday', basic emotions (Zentner, Scherer & Grandjean, 2008). Therefore, the phenomenon of chills serves as a focussed, unique opportunity to not only assess and understand a specific incidence of intense musical emotion, but to crucially extend findings to two broader contextual levels, namely that of underlying mechanisms of music and emotion, and the more general context of emotion science and theory.

The aims of this current dissertation are aligned with the central limitations of musical chills research. Firstly, this work aims to explore and understand more extensively the emotional qualities and characteristics of musical chills, the situations in which they typically occur, and the broader corpus of music that might be most effective at eliciting the response. Secondly, the current project aims to carry out essential causal investigations of musical chills, by developing an experimental paradigm focussed on manipulating musical structures and features linked to the response, and assessing changes in the subsequent experience of listeners; in turn, this procedure might allow for the first testing of theories or explanations of musical chills to be carried out. Finally, this research aspires to comprehensively cover, extend and formalise theories of musical chills, and through these developments assess whether chills are a singular, coherent psychological construct, or rather a collection of distinct emotional states that share a common psychophysiological index. With these central objectives briefly stated here, the formalised research questions will be presented at the end of **Chapter 3**, following a critical review of the musical chills phenomenon. However, before addressing the induction of musical emotions and chills specifically, it is crucial, for the sake of transparency, framing and clarity, to address and briefly establish the broader contexts that this dissertation also aims to inform. Whilst the underlying mechanisms of music and emotion will be discussed in **Chapter 2**, the remainder of this introductory chapter will overview the broader topic of emotion science and theory, arrive at some operationalisation of emotion to be utilised in this research project, and within this emotion context summarise the debate on whether music can elicit emotions; the chapter will then conclude with a structural overview of the remainder of the current project.

1.2 Emotion

The concept of an emotion has a long history through philosophical thought and, more recently, experimental psychology; it has been the subject, under different guises and nomenclature, of contemplation, analysis and discussion, dating back to Ancient Greece, with Aristotle and discussions of the *passions*, or Plato describing emotion and reason as antagonistic, opposing forces. Across earlier philosophers, emotions were understood as a category of feelings, distinct from other proprioceptive or sensory sensations. However, experimental psychology approaches emerged and progressed from the 19th Century onwards, alongside philosophical thought; this resulted in several perspectives and conceptualisations of emotions, and theories of their function and elicitation. Consequently, the modern field of emotion science grapples with the difficulty of arriving at a consensual definition of what an emotion constitutes (Izard, 2007). Some emotions appear to be automatic, consistent and universal (Ekman, 1999; Ekman & Davidson, 1994), and yet other behaviours and responses are best understood in socio-cultural contexts (Barrett, 2006a; Mesquita, Barrett & Smith, 2010); further still, there are discussions regarding whether emotional experiences are perceived through changes in autonomous physiological activity, and how these relate to contextual factors (James, 1884; Russell, 2003; Schachter & Singer, 1962), or whether these changes in psychophysiology are a result of cognitive processing and appraisals of external events and situations (Frijda, 1986; Lazarus, 1991; Scherer, Schorr & Johnstone, 2001). Finally, and pertinent for conceptualising musical emotions, is the distinction between basic and complex emotions (Ekman & Cortado, 2011; Ortony & Turner, 1990), that resembles a distinction raised elsewhere between utilitarian and aesthetic emotions (Zentner et al., 2008). What follows is a brief overview of prominent emotion theories and their limitations, followed by a tentative, working operationalisation of emotion for the purposes of the current research project.

1.2.1 Theories of Emotion

Across differing epistemological approaches and disciplines, emotions are defined, conceptualised and understood in a multitude of ways, referring to the causation process of emotion, discrete or dimensional models of emotion, and components or characteristics of the emotions themselves. For current purposes, central theoretical stances on emotion as distinguished by Gross and Barrett (2011) will be addressed, labelled as *basic emotion, appraisal, psychological constructionism*, and *social constructionism*.

Basic Emotion

The theory of basic emotions is derived from, and reflects, the observation of distinct behavioural expressions of emotions across humans and other animals, originally documented by Darwin (1872) and further developed by claims of universal facial expressions of certain emotions (e.g. Ekman & Friesen, 1971). The theory proposes that there exist basic, irreducible emotions that are a product of evolution (Izard, 2007); these are adaptive, universal, biologically prewired (Ekman & Cortado, 2011), and are discrete in terms of behavioural outcomes and expression (Darwin, 1872), psychophysiological response (Ekman, Levenson & Friesen, 1983), and neurophysiological activity (Davidson, Ekman, Saron, Senulis & Friesen, 1990; Ekman, Davidson & Friesen, 1990). A common example of a basic emotion may be fear, a response often cited in support of the theory. Fear has been characterised as a behavioural motivator in response to threat or danger (Gray, 1987), appears to reflect a level of consistency in psychophysiological response patterns (Kreibig, 2010), and seems to be processed largely by the amygdala (LeDoux, 2003; Wilensky, Schafe, Kristensen & LeDoux, 2006).

The theory has been an attractive approach to emotion, and has historically accrued some support and evidence in the form of facial expressions (Ekman, Sorenson & Friesen, 1969; Tomkins & McCarter, 1964), psychophysiology, and elicitors (Ekman & Davidson, 1994). Ekman and Cordaro (2011) proposed that a basic emotion should ascribe to 13 characteristics, building on earlier work by Ekman

(2003; 1992); some of these characteristics include quick onsets, brief duration, and distinctive universality, physiology and antecedent events. Notably, basic emotion perspectives have been adopted across numerous proposed mechanisms of music and emotion (Juslin, 2013). However, one of the main criticisms regarding this theory is that the main proponents of this approach fail to agree on which emotions are basic, and how many there are. Emotions designated as basic have included joy, anger, fear, sadness, disgust, shame, surprise, contempt, interest, guilt, acceptance and anticipation (Ekman, 1973; Izard, 1971; Panksepp, 1982; Plutchik, 1980; Tomkins, 1984); notably, researchers disagree on how many emotions are classified as basic, ranging from two in pleasure and pain (Mowrer, 1960), to 18 (Frijda, 1986), with significant variability in between. Basic emotions are said to provide foundations for non-basic, more complex emotions such as nostalgia, although this has also been contested by Ortony and Turner (1990). Furthermore, through the development of neuroimaging and brain scanning technology, there is still a lack of strong evidence for distinct circuitry or systems in the brain dedicated to distinguishable basic emotion families; returning to the fear example, whilst the amygdala is often implicated (Davis, 1992), this component of the brain is also central to other emotional processes beyond fear (Lindquist, Wager, Kober, Bliss-Moreau & Barrett, 2012; Murray, 2007), such as emotion recognition in music (Gosselin, Peretz, Johnsen & Adolphs, 2007), bringing into disrepute the presence of specific, localised brain areas attributed to certain emotions.

Appraisals

Across various advocacies of basic emotion theory, it has been implied that there is a direct relationship between event or stimulus, and elicitation of emotion; with regards to basic emotions, the causation process is automatic, adaptive and universal. In contrast, appraisal theory places an emphasis on how we judge, assess and understand these events and stimuli. In simple terms, appraisal theory claims that rather than the events or stimuli themselves, it is our appraisal and evaluation of them that elicits emotions (Roseman & Smith, 2001). This tradition developed from the original ideas of Arnold (1960), and has been supported since by numerous researchers (Frijda, 2007; Lazarus, 1991; Scherer et al., 2001); moreover, the process of cognitive appraisal has been utilised in discussions on music and emotion (Scherer & Coutinho, 2013; Scherer & Zentner, 2001; Warrenburg, in press). In more detail, it is suggested that distinct appraisal patterns differentiate between emotions (Frijda, 1986; Lazarus, 1991; Scherer, 1984; Smith & Ellsworth, 1985), for example determining levels of intensity, and the characteristics of emotional responses (Frijda, 2007; Scherer et al., 2001). More recently, the process of appraisal has been conceptualised as the fulfilment or obstruction of a person's goals or concerns (Moors, Ellsworth, Scherer & Frijda, 2013), including attachments, values, beliefs and needs (Scherer, 2004).

Appraisal theory has been recruited to explain several issues with other approaches, such as basic emotion perspectives; for example, there is the issue of the same event or stimulus being able to elicit a wide variety of emotions across different individuals (Smith & Pope, 1992), and within the same individual at different times. A related, further issue is that for any discrete emotion, there appears to be a wide array of events and stimuli that have the capacity to be an elicitor. Our evaluation of events is one possible explanation for these observations, with a variety of factors that may determine the consequential emotion, such as predictability of the event, control of the event outcomes, and whether oneself or someone else caused the event (Moors et al., 2013). Whilst researchers advocating for appraisals underlying emotion perhaps agree on more aspects compared to other approaches (a notable exception is the emotion and cognition primacy debate, see Lazarus, 1982; 1984; Zajonc 1980; 1984), there are further difficulties and points of contention with appraisal theory, such as the directionality of causation between emotions and appraisals, with evidence for appraisals eliciting emotions (Smith & Lazarus, 1993), and vice-versa (Lerner & Keltner, 2001). In addition, whilst negative emotions are more clearly conceptualised in relation to appraisals, there is less evidence and research for positive and complex emotions, such as awe, serenity and gratitude (Tong & Jia, 2017).

Psychological and Social Constructionism

The final perspectives to consider are constructionist approaches to emotion, labelled by Gross and Barrett (2011) as psychological constructionism and social constructionism. These approaches sit in contrast to basic emotion perspectives, and place an emphasis, to differing degrees, on the effects of events or stimuli, culture, society, somatic markers, and perception of physiological changes as determinants of the subsequent emotional response.

The psychological constructionist ideas of emotion can be attributed to early influential work by James (1884; 1894) and Lange (1885), who suggested that we might experience emotion in response to our interpretations of psychophysiological changes and activity, as opposed to external events and stimuli; in this formulation, encountering a bear would not be the elicitor of an emotional response, but instead it would be the increases in physiological arousal that are perceived within oneself. Some historical evidence is presented in a study by Schachter and Singer (1962), who administered participants with either a placebo or dose of epinephrine (i.e. adrenalin); this dosage resulted in heart rate increases, respiration rate increases, and other changes in blood pressure and blood flow. Notably, these changes in physiological activity were shown to affect the cognitive assessments of participants' emotional experiences, but only when there was no satisfactory explanation given regarding their physiological state beforehand. This perspective has received increased attention more recently, in response to evidence inconsistent with the idea of basic emotions and corresponding causal mechanisms, autonomic activity and anatomical patterns of response (Barrett, 2006a). For example, Russell (2003) described 'core affect', a continuous, simple, raw component of feeling, organised into dimensions of valence of arousal; changes in core affect can be biological, neurochemical and homeostatic, but may also be event-related. Another example is the conceptual act model proposed by Barrett (2006b), suggesting that feeling or observing an emotion occurs when conceptual knowledge of emotion is utilised to categorise a state of core affect in relation to an event or scenario; this approach places an emphasis on learning, enculturation and language, is somewhat adjacent to certain appraisal perspectives, and characterises emotional experiences as a process of active categorisation as opposed to a reactionary, evolutionary mechanism. How core affect interacts with perception, cognition, appraisals, actions and emotion regulation remains a central point of emphasis in psychological construction research.

The social constructionist perspective instead places a further emphasis on sociocultural contexts, and how these determine emotional responses. This approach focusses on emotions as emerging properties of ongoing social interactions and situations (Averall, 1980; Harré, 1986). Importantly, it is not that emotions are reactions to social events *per se*, but rather both emotions and social interactions comprise one foundational system (Barrett, 2013; Butler, 2011). For example, Boiger and Mesquita (2012) suggest that emotions change dynamically throughout social interactions, contingent on how someone responds to one's own emotional behaviour, and vice-versa. Furthermore, it is proposed that the existing relationships between people afford certain emotional emergence during future interactions; by extension, as interactions are shaped by culture (Mesquita, 2001), the dynamic development of emotion is claimed to be a product of evolving sociocultural circumstances. The social constructionist theory of emotion has been utilised to assess musical emotions (Cespedes-Guevara & Eerola, 2018), and attempts to address a shortcoming of numerous other models of emotion, namely that most emotional experiences occur in social interaction (Mesquita & Boiger, 2012). However, whilst constructionist perspectives are promising and encompass the complexities of affective experience, the ideas are difficult to test and probe experimentally, and there remains a crucial challenge in bridging the gap between experimental psychology and sociological formulations of emotion.

1.2.2 A Working Definition of Emotion

Across the wealth of existing research in emotion science, there are agreements and disagreements on the construct of emotion; the main theoretical perspectives that have gained traction have explanatory power, yet each have corresponding limitations. However, whilst it is difficult to develop an operationalisation of emotion that is satisfactory for all researchers, it is essential to have some working definition that frames the analysis, interpretation and discussion of the data or research. Pertinently, some characteristics of an emotional response are generally agreed upon by researchers in the field. An emotion is often understood, in multicomponent models (Scherer, 2009), to involve changes in numerous components in response to an event; these components include subjective feeling, physiological reactions, action tendencies or readiness, behaviour and expression, and cognitive appraisal. In addition, it is expected that most emotional responses show an observable synchrony or correspondence between these components; for example, changes in subjective feeling may coincide with physiological changes or facial expressions.

In the current project, no strong stance is taken regarding theoretical positions on emotion induction, regulation or construction; it is hoped that this will allow this specific project on musical chills to flexibly inform and build upon emotion science research, including the basic emotion, appraisal and constructionist perspectives. Instead, a current working definition of emotion is largely derived from the multiple outcome components of emotion; importantly, as will be reviewed in **Chapter 3**, musical chills are a significant example of several emotion components that appear to co-occur in time. Therefore, the current working definition of emotion follows this componential perspective on experience, characterising emotions as an event-related, affective response that shows observable synchrony across multiple components such as subjective feeling, physiological reactions and behavioural or expressive aspects; this operationalisation will guide the experimental methodologies employed in the current project. It is important to add that whilst theoretical discussions of musical chills may at times emphasise aspects linked to certain perspectives on emotion, no theory of emotion induction or categorisation is subscribed to, and these differing perspectives are crucial to consider in understanding emotions with music. A final, important aspect to note is that emotions in the present circumstances are distinguished from mood (Juslin & Sloboda, 2010b); emotions are presently characterised as shorter in duration and of a higher intensity than mood states.

1.3 Can Music Induce Emotion?

With a usable, working definition of emotion in place, it is important to consider briefly an ongoing debate in music and emotion research, namely whether music can elicit emotions in listeners; this may be a surprising debate, considering the self-reported importance of emotion in music for listeners (Juslin, Liljeström, Västfjäll, Barradas & Silva, 2008). However, when considering emotions as adaptive responses to salient external events and stimuli, linked to goal relevance and survival, it is not immediately intuitive to see music as an effective elicitor of emotional responses (Huron. 2001). It is crucial here to distinguish emotions *felt* with music from the emotions *perceived* within the music; the expression of emotion in music is perhaps less contentious, with evidence for communication of emotion in musical performances (Juslin, 2001; Juslin & Timmers, 2010), common acoustic and structural cues underlying expression (Gabrielsson & Juslin, 2003; Hailstone et al., 2009; Hevner, 1935; 1936), and emotion recognition abilities that seem present across cultures (Balkwill & Thompson, 1999; Balkwill, Thompson & Matsunaga, 2004; Fritz et al., 2009). In contrast to emotion recognition, the following discussion addresses work arguing against the elicitation of emotions through music, a further distinction between utilitarian and aesthetic emotions aimed at subverting difficulties surrounding musical emotions, and a final summary of empirical evidence suggesting, particularly in the context of the present definition of emotion, that music can elicit genuine emotional responses in listeners.

1.3.1 Against Musically Induced Emotions

The claim that music is unable to elicit emotions in listeners is not new, with an opposing stance presented from as early as Hanslick (1854/1986), who suggested that music cannot be understood in relation to aspects or factors external to music, and that music instead expresses strictly musical ideas. Further contributions from music philosophy describe musical emotions as an error, in which listeners mistake a general, unfocused excitement for the emotional qualities perceived within the music (Davies, 1994). However, as argued by Zentner et al. (2008), these errors are not likely to be pervasive, as whilst there are times where perceived and felt emotions with music are comparable (Gabrielsson, 2002), it is not always the case (Evans & Schubert, 2008; Hunter, Schellenberg & Schimmack, 2010; Kallinen & Ravaja, 2006).

More recently, Konečni (2008) developed a more direct thesis against musical emotions, highlighting that emotions are not directly elicited by music, but instead through associative psychological processes such as memories or visual imagery. This conclusion followed a critique of numerous empirical studies from Krumhansl (1997), Waterman (1996) and Witvliet and Vrana (1996), highlighting numerous methodological concerns: Firstly, when psychophysiological responses were recorded in response to music, researchers did not collect self-report ratings regarding participant's emotional states (Witvliet & Vrana, 1996); secondly, asking participants to press a button when the music causes something to happen fails to capture any cognitive appraisal dimensions of a genuine emotional reaction (Waterman, 1996); finally, the continuous rating paradigm employed by Krumhansl (1997) possibly introduced cognitive load interferences in participants, increasing the likelihood that they rate in real time the musical expression, rather than their felt emotional state; this has continued to be a difficult issue in continuous rating paradigms used in music and emotion studies (Schubert, 2013; Upham & McAdams, 2018). These methodological issues raised by Konečni (2008) are important to consider, and it is likely that in many cases music may induce emotions through associative processes and not directly; despite this, if music is the original source of this affective sequence, the impact of associative processes on the question of musical emotions may be primarily an epistemological concern, and the focus might shift to whether music is a unique starting point in this sequence, as opposed to other stimuli.

1.3.2 Utilitarian and Aesthetic Emotions

A further point of contention in the literature is whether musical emotions are comparable to emotions more broadly conceptualised in traditional emotion theory work. In a study by Zentner et al. (2008), this contention was investigated by assessing the qualities and characteristics of musical emotions, and whether they are distinct from non-musical emotional experiences, thus requiring a domain-specific measurement approach. For example, discrete emotions derived from environmental events and appraisals are of a high intensity, work to organise behavioural and bodily response, and often result in goal-directed behaviour (Ekman, 1992; Izard, 2007); however, this is not easily or often observed when it comes to emotions with music, suggesting that there may be important distinctions between *utilitarian* and *aesthetic* emotions (Zentner et al., 2008). Results from this study highlighted that typical scales, models and descriptors used in non-musical emotion studies were not sufficiently nuanced to capture emotional responses to music, with the subsequent proposal and development of the Geneva Emotional Music Scale (GEMS). A similar distinction was presented by Frijda and Sundararajan (2007) between *coarse* and *refined* emotions; in this formulation, refined emotions are not encapsulated by common emotion labels, and are not necessarily accompanied by overt behaviours and actions, instead involving more subjective feelings in response to complex events. Concordantly, aesthetic emotions may be characterised by detachment and distance from pragmatic life concerns, and these are hypothesised to be expressed with fewer overt motor actions and behaviours, lower levels of physiological response, and are more grounded in experiential and feeling components (Scherer, 2004; Zentner et al., 2008). Detachment and distance from real dangers, threats and concerns has been highlighted elsewhere in the aesthetic trinity theory (Konečni, 2005), and in the recent distance-embracing model of enjoying negative emotions in art (Menninghaus et al., 2017), as an important aspect of aesthetic emotion. Music then may allow for a safe context in which to explore and engage with emotional characters and qualities that may be maladaptive in utilitarian circumstances. However, whilst this distinction is important to consider, it is again subject to differing perspectives on emotion theory more broadly; for example, appraisal perspectives may require the utilitarian and aesthetic separation to maintain explanatory power, whereas constructionist approaches may more efficiently encapsulate emotions across these different contexts. Importantly, if there is a case to distinguish aesthetic emotions, there is currently little understanding as to how these may have evolved over time, and for what purpose.

1.3.3 Evidence for Music-Induced Emotion

Despite the debates surrounding whether music can directly elicit emotional responses, and whether musical emotions should be characterised differently from more adaptive emotions, the common view amongst researchers is that music is able to elicit genuine emotional responses in listeners, and there has been a growing range of evidence across studies that support this perspective. In the present, working definition of emotion, emotional responses should demonstrate observable or measurable subjective feeling components, psychophysiological and bodily activity, motor responses, and a degree of synchrony or concurrence across these aspects (Scherer, 2009). With regards to subjective feeling components, there are plethora of self-reports (Lundqvist, Carlsson, Hilmersson & Juslin, 2009), retrospective accounts (Gabrielsson, 2011), and experience sampling data (Juslin et al., 2008; Randall, Rickard & Vella-Brodrick, 2014; Sloboda, O'Neill & Ivaldi, 2001), highlighting the prevalence of emotional experiences with music (Gabrielsson, 2011). With regards to psychophysiological responses, music has been shown to affect a variety of measures, such as heart rate (Koelsch & Jäncke, 2015), pupil dilation (Laeng, Eidet, Sulutvedt & Panksepp, 2016), and skin conductance (Khalfa, Peretz, Blondin & Manon, 2002; Nykliček, Thayer & Van Doornen, 1997; Rickard, 2004; Salimpoor, Benovoy, Longo, Cooperstock & Zatorre, 2009). Regarding facial expression, numerous studies have utilised facial electromyography techniques (EMG) to assess facial, muscular activity in reaction to music listening experiences (Krumhansl, 1997; Lundqvist et al., 2009). Further neuroimaging work has consistently documented brain activity during music listening that is implicated in the processing of reward and emotions (Gold et al., 2019; Koelsch, 2014; Menon & Levitin, 2005; Zatorre & Salimpoor, 2013); notoriously however, this activity is difficult to attribute to any specific emotional experience in listeners. Finally, the perceptual processing of music has received neurophysiological attention in the literature, and there are numerous electroencephalography (EEG) and magnetoencephalography (MEG) studies that link music to various event-related potentials associated with novelty detection and processing, such as the N400 (Koelsch et al., 2004), and syntactically sensitive early right anterior negativity (Maess, Koelsch, Gunter & Friederici, 2001); notably, when emotions are discussed as goal-oriented responses involving cognitive appraisal mechanisms, novelty and unexpectedness are primary candidates that determine whether and event is adaptively relevant for an individual (Ellsworth & Scherer, 2003), further linking music to the elicitation of genuine emotional responses.

With regards to synchrony across components such as subjective feeling, psychophysiological activity and motor responses, this has also been documented to an extent by Lundqvist et al. (2009), who found evidence for coherent emotional responses showing alignment across self-reported experience, physiological activity, and expression (facial EMG); for example, happy music resulted in increased zygomatic muscle activity (i.e. smiling), skin conductance, happiness ratings, and decreases in skin temperature, when compared to sad music. A pertinent example of notable synchrony across components of emotional response is that of musical chills, the strong emotional phenomenon of central focus in the current research project.

1.4 Overview of the Current Research Project

In summarising the existing research, both within music psychology and across the broader domain of emotion science, the concept of emotion has been operationalised, and subsequently shown to be linked empirically to musical engagement and listening experiences. Within this larger context, musical chills experiences serve as a phenomenon worthy of investigation for three reasons: Firstly, understanding and testing the chills response will aid in developing causal approaches to music and emotion studies; secondly, elucidating the theoretical underpinnings of chills should help to inform the theories and musically induced emotions discourse, in relation to proposed psychological mechanisms and existing debates; finally, at the broadest contextual level, the investigation of musical chills may help to inform emotion theories and their application or evocation in the domain of music psychology (Cespedes-Guevara & Eerola, 2018). Regarding this final point, it is essential to note that the framing and contextualisation of research guides and shapes assumptions, predictions and interpretations, and as highlighted earlier in this chapter, it is useful to restate that whilst one operationalisation of emotion was adopted here, there are further possibilities of approaching musical emotions, and the chills response, from different theoretical perspectives.

The current thesis will be organised as follows. In **Chapter 2**, a review of proposed psychological mechanisms and induction processes for musical emotions will be addressed, with a central focus on the BRECVEMA framework posited by Juslin and Västfjäll (2008), and developed further since (Juslin, 2013; Juslin, Liljeström, Västfjäll, & Lundqvist, 2010). Understanding some of hypothesised routes of emotion induction during music listening provides a crucial additional context (alongside emotion theory contexts presently established) for the studies and investigations of musical chills reported in this project, and allows for this dissertation to inform discourse in broader music and emotion work.

In **Chapter 3**, a critical, extensive literature review on the chills phenomenon will be presented; this will address definitional issues surrounding chills, the existing research on musical and broader aesthetic chills, a development, extension and formalisation of two main theories of chills, and the current difficulties associated with how researchers currently conceptualise the response. From this, three central, substantial limitations of current research on musical chills are highlighted, with corresponding main research questions formally stated, addressing the fundamental shortcomings of the present understanding of the phenomenon.

In **Chapter 4**, a qualitative survey study on musical chills experiences will be presented, in which significant questions were investigated regarding the emotional characteristics of chills, typical listening situations in which they occur, and the variety of pieces of music effective at eliciting chills, with a specific focus on musical features and characteristics linked to the response.

In **Chapter 5**, a listening experiment is documented that aimed to, for the first time, manipulate chills experiences empirically, by removing salient sections in three pieces of music closely associated with chills; this study suggests that chills can be manipulated with the correct stimuli and experimental procedure, serving as a proof of concept foundation for further, more subtle manipulations of the phenomenon.

In **Chapter 6**, a second listening experiment is described which attempted to refine the manipulation paradigm, and aimed to test a theory of musical chills for the first time. By increasing or decreasing loudness and spectral brightness in two chills excerpts, partial support for a vigilance theory of musical chills was found, although these effects were clear in only one of the two pieces, suggesting important interactions between the underlying musical structure and psychoacoustic manipulations.

In **Chapter 7**, a web-study is reported which addresses the crucial question regarding how chills are conceptualised, and whether chills are a unified psychological construct, or a collection of distinct, separable experiences. Using multimedia stimuli from an online forum dedicated to 'frisson' and musical stimuli from **Chapter 5**, evidence was found for at least three categories of chills, namely *warm, cold* and *moving* chills, suggesting, in a broader context, that some chills may be psychologically distinct from others, with substantial implications for musical chills research.

In **Chapter 8**, a final listening experiment is presented that aimed to address the possibility of distinct chills experiences specifically in the context of music listening; in reviewing theories and findings linked to chills, including those derived from the current research project, a distinction was hypothesised between *vigilance chills* and *social chills*. This experiment was designed to find evidence for this distinction in terms of stimulus manipulations, subjective feeling, psychophysiological activity, and individual differences in preferred cognitive processing styles, with results support these predictions.

In **Chapter 9** of the thesis, a general discussion that encapsulates the five main studies carried out for the current research project is provided; this discussion highlights how the results from this project relate to the existing literature on chills, and where appropriate how the present findings have substantial implications on the accuracy and interpretation of previous work on the phenomenon. Furthermore, the five studies will be situated in the two broader contexts of musically induced emotions, and emotion science and theory. As a final, central contribution of this project, a *Framework of Distinct Musical Chills* will be introduced, describing at least two chills categories, and how they are distinguished at the level of elicitors, underlying psychological mechanisms, subjective feeling components, physiological activity, and individual differences across listeners. Alongside this, a new research agenda will be proposed, with hopes that future research considers carefully what exactly is being studied when investigating musical chills, how we might move forward with the causal manipulation approach, and the importance of developing from the proposed conceptualisation of chills as a collection of psychologically distinct experiences.

2. Psychological Mechanisms of Musical Emotion

In **Chapter 1**, multiple studies and investigations were summarised, offering support to the claim that music can elicit genuine emotional states in listeners. Whilst this continues to be evidenced by self-report data, psychophysiological activity, and neuroimaging work, a crucial question for researchers is *how* music might be able to elicit emotions. This is difficult to approach, especially given that emotional experiences during music listening are a product of complex interactions between characteristics of the music, individual traits and prevailing mood state of the listener, and the situation or context in which the listening episode takes place (North & Hargreaves, 2008). As a result, studies that attempt to causally test existing theories of emotion induction through music are relatively rare; this is also a severe problem in musical chills research. However, there are theories and explanations posited as to how music can elicit emotion; the most effective starting point, and prevailing music and emotion context for this project on chills, is the BRECVEMA framework (Juslin, 2013).

The current chapter firstly introduces the BRECVEMA framework, and presents the corresponding psychological mechanisms suggested to underlie musically induced emotions. The possible limitations of the framework will then be assessed, with the conclusion of the chapter finalising and establishing the context and foundations for critically reviewing the extant research and theoretical discourse on the musical chills phenomenon.

2.1 The BRECVEMA Framework

In the original formulation of a framework for underlying, psychological mechanisms of music and emotion, Juslin and Västfjäll (2008) proposed six induction routes for emotional responses with music. These mechanisms were formulated on the basis that they were evidenced by the broader literature on music and emotion, they reflected processes that generalise beyond music, and that these processes were evolutionarily adaptive. Two further mechanisms were later added (Juslin, 2013; Juslin et al., 2010), resulting in the present BRECVEMA framework. The proposed mechanisms comprising this framework are *brain stem reflexes, rhythmic entrainment, evaluative conditioning, contagion, visual imagery, episodic memory, musical expectancy*, and *aesthetic judgment*. These processes may be conceptualised as a series of hypotheses regarding musical emotions, and whilst they appear to be testable, a sparse research agenda has developed to approach these mechanisms, though some recent progress has been made (Juslin, Barradas, & Eerola, 2015; Juslin, Harmat, & Eerola, 2014; Juslin & Isaksson, 2014). What follows is an overview and explanation of each mechanism, and a summary of other potential induction processes not encapsulated by the BRECVEMA framework. This review serves to contextualise the forthcoming causal considerations of musical chills, and existing theories for the phenomenon.

2.1.1 Brain Stem Reflexes

Brain stem reflexes can be described as an automatic, rapid reaction to potentially important changes or events in one’s environment (Juslin & Västfjäll, 2008). Although it has rarely received an extensive formulation, the reflex appears comparable to both the orienting response and startle reflex; however, brain stem reflexes are likely a more intense response than the mild, continuous orienting response described by Sokolov (1963), but perhaps less intense than the widely-documented startle reflex (Lang, Bradley & Cuthbert, 1990; Miller, Patrick & Levenston, 2002). The response is produced in ancient structures of the brain stem, involving areas such as the inferior colliculus (Brandão, Melo & Cardoso, 1993) and intralaminar nucleus of the thalamus (Juslin, 2013). Interestingly, little research on music and emotion has directly assessed the brain stem reflex, and little is known of the nature of the response; one study attempted to manipulate this mechanism however (Juslin et al., 2015), suggesting that the process resulted in experiences of surprise during music listening. Generally, it is not clear what characteristics of music elicit this response, although sudden dynamic changes or dissonance could be plausible candidates (Juslin, 2013). Furthermore, it is not known as to whether the mechanism can be modulated, or whether it expresses habituation through repeated exposure to an elicitor, as is the case with the related startle reflex (Bradley, Cuthbert & Lang, 1990; Grillon & Baas, 2003).

2.1.2 Rhythmic Entrainment

One of the more recent additions to the proposed underlying mechanisms of music and emotion is rhythmic entrainment. Entrainment to an external rhythm appears to be a ubiquitous human phenomenon (although for evidence of entrainment in other animals, see Patel, Iversen, Bregman & Schulz, 2009), and a central component of musical ensemble performance (Clayton, 2007; Doffman, 2009; Keller, 2014). In formalising entrainment, Clayton, Sager and Will (2005) suggested that entrainment is '*a process whereby two rhythmic processes interact with each other in such a way that they adjust towards and eventually "lock in" to a common phase and/or* *periodicity'* (p. 2). As a process, rhythmic entrainment abilities may have been naturally selected through evolution as an effective means of coordinating actions across larger groups; indeed, the mechanism has recently been suggested to serve social functions (Kirschner & Tomasello, 2009; 2010), and may act as a facilitator for empathy and altruistic action (Cirelli, Einarson & Trainor, 2014). In the case of music listening, rhythmic entrainment can be evidenced through overt behavioural responses to the music, with related lower-level sensorimotor synchronisation performance being meticulously studied using finger tapping paradigms (Repp & Su, 2013). In contrast, within the BRECVEMA framework, Juslin (2013) presents rhythmic entrainment specifically as the effect of external musical rhythms on internal biological rhythms such as heart rate; from this, emotions may be elicited through proprioceptive feedback processes (Scherer & Coutinho, 2013; Scherer & Zentner, 2001), in which emotions are experienced through perceiving one's own changes in physiological activity, a process aligned closely with psychological constructionist theories of emotion (Barrett, 2006b; James, 1894; Lange, 1885; Russell, 2003; Schachter & Singer, 1962). Furthermore, the subsequent emotional experience may reflect those commonly associated with the physiological changes perceived; in the case of rhythmic entrainment resulting in increased heart rate for example, a high arousal emotional response might be predicted. However, the restriction of rhythmic entrainment to biological rhythm changes is likely insufficient to describe the various affective consequences of the mechanism. For example, Trost, Labbé and Grandjean (2017) note that rhythmic entrainment may induce affect at several levels, including neural, perceptual, physiological, motor and social levels; moreover, Labbé and Grandjean (2014) claimed that rhythmic entrainment was comprised of a visceral (sensations of internal bodily entrainment) and motor (inclination to move with the music) component, with various affective consequences. Of current importance is entrainment at the social level, an aspect that might be speculatively associated with musical chills experiences; rhythmic entrainment with music may not only facilitate large scale synchrony, for example amongst a rock concert audience (Néda, Ravasz, Brechet, Vicsek & Barabási, 2000), but also facilitates a level of synchrony between listener and music. Interestingly, synchrony, and to some extent mimicry, has been linked to more positive interpersonal engagements (Chartrand & Bargh, 1999; Kühn et al., 2010), and Koelsch (2010) suggests that entraining to music, or with others during a musical engagement, may elicit affective experiences such as communion, unity and a sense of belonging. As will be seen in **Chapter 3**, these interpersonal and communal aspects are essential components of one theory of musical chills linked to social bonding.

2.1.3 Evaluative Conditioning

The third mechanism in the BRECVEMA framework is evaluative conditioning, which refers to the changing of affective quality or valence of a stimulus, due to pairing with another positive or negative stimulus (Hofmann, De Houwer, Perugini, Baeyens & Crombez, 2010). In the musical context, a piece of music may induce emotions in a listener through its previous pairing with another event with marked emotional value and character. For example, consider music playing alongside an emotional reunion between two close friends; in these cases, music serves as the conditioned stimulus, or the stimulus in which affective qualities are altered, through pairing with an affectively charged, unconditioned stimulus. Whilst the phenomenon of evaluative conditioning has received considerable attention in broader literature (De Houwer, Thomas & Baeyens, 2001; Field & Moore, 2005; Hofmann et al., 2010;

Walther, Nagengast & Trasselli, 2005), there is less work carried out in the musical context. One of the few studies involving music was carried out by Blair and Shimp (1992), in which a mundane task was carried out by participants over several days, either with no music, background music, or background music only on the final day of the task; data suggested that the evaluation of the music at the end of the study was influenced by the mundane task it was repeatedly paired with, suggesting that the evaluative conditioning mechanism is applicable to some instances of musical engagement. Interestingly, music has also been utilised as the unconditioned stimulus, to influence conditioned responses to Greek letters (Eifert, Craill, Carey & O'Connor, 1988). A central limitation with this mechanism, alongside the sparsity of literature, is that music is rarely a neutral, conditioned stimulus, and in fact listeners may attribute and experience affective responses quickly upon first hearing the music in question, resulting from enculturation processes or innate preference for certain sounds. However, conditioning effects are pertinent when discussing musical emotions, and may be important for some chills responses, especially when considering repeated exposure and familiarity effects in musical engagements.

2.1.4 Contagion

At a basic level, emotional contagion may be defined as the internal mimicry of perceived emotional expression, that subsequently results in experiencing the same or similar emotion; this may be achieved through the activation of associated muscles or physiology, or appropriate representations of perceived emotions within the brain (Juslin & Västfjäll, 2008). Dezecache, Jacob and Grèzes (2015) describe contagion as a two-step model: Firstly, the perception of behaviour leads to a replication in the perceiver; and secondly, this replication causes the perceiver to experience the same affective state as that observed. As an example, we may observe and replicate a smiling face, which through proprioceptive feedback processes, results in us experiencing the emotions attributed to this muscular expression (see Strack, Martin & Stepper, 1988). Notably, in the current project contagion is conceptualised as a special, low-level process generally distinct from empathy; it must be noted however that some researchers consider contagion as a type of empathic process (Clarke, DeNora & Vuoskoski, 2015).

Contagion has been implicated more frequently in music and emotion research compared to other mechanisms, and the process has been recruited to explain numerous phenomena, such as the similarities between perceived and felt emotions with music (Gabrielsson, 2002). The process is difficult to explain however, especially in relation to how music expresses emotions to listeners consistently, and how this transfers to the emotional experiences of listeners. A central process underlying contagion mechanisms in music and emotion is that of perception and action loops and the mirror neuron system. This system describes a mechanism of understanding and interpreting perceived actions and intentionality. These mirror neurons fire both when perceiving an action or behaviour, and when performing the same action (Rizzolatti & Craighero, 2004); in addition, this process may occur through both seeing and hearing an action (Kohler et al., 2002). As these mirror neurons may code perceived motor behaviours in terms of a broader sequence, they may allow predictions of the intentions behind the actions (Fogassi et al., 2005). Importantly for the present research, the affective qualities underlying certain goals or intentions might also be included in this mirror neuron response, preparing the observer to feel and act in a comparable manner. Naturally, this system has been implicated in numerous communicative, social processes such as empathy and theory of mind (Gallese, 2003; Williams et al., 2006), with Molnar-Szakacs and Overy (2006) recruiting the system to explain emotional experiences with music. As music is mostly a product of motor activity and social behaviour, it is suggested in the Shared Affective Music Experience (SAME) model (Overy & Molnar-Szakacs, 2009) that by perceiving hierarchically organised, goal-directed actions in music, listeners co-represent the musical experience with performers, and mirror the emotional experiences or affective qualities underlying these actions, as if performed by the listeners themselves. This is not wholly different from theories of musical expression, such that music embodies an emotional characteristic due to its resemblance to physical posture, gesture and human expression (Davies, 1994; Ilie & Thompson, 2006; Irrgang & Egermann, 2016; Juslin & Laukka, 2003; Kivy, 1980; 2002; Kohn & Eitan, 2016); however, the SAME model offers a neurobiological, domain-general process involving human mirror neurons and the limbic system (Overy & Molnar-Szakacs, 2009).

The mirror neurons and perception-action links are possible explanations for the emotional contagion process, and whilst the contagion mechanism is difficult to test causally, it may be linked to social experiences with music; like entrainment processes, the sharing and co-representation of emotional responses between listener and performer or character may result in further experiences of communion or bonding, which in the following chapter will be staged as significant processes for the musical chills phenomena.

2.1.5 Visual Imagery

The fifth mechanism of visual imagery describes the process of conjuring internalised visual images during a music listening episode, such as natural landscapes, events, people, and plethora of other scenes. In contrast to several other mechanisms, visual images are highly available to consciousness, and carry survival value by simulating consequences of further actions or events (Juslin, 2013), or by imagining different scenarios to understand our environments (Plutchik, 1994). Historically, associations between visual imagery and emotional responses have been suggested (Grossberg & Wilson, 1968; Holmes & Mathews, 2005), and it appears likely that visual images produced whilst listening to music are pervasive (Küssner & Eerola, 2019; Taruffi, Pehrs, Skouras & Koelsch, 2017; Vuoskoski & Eerola, 2015). Despite this, visual imagery has received little attention in music and emotion research. McKinney and Tims (1995) suggested that individual differences may predict which listeners experience more vivid images whilst listening to classical music. Through ethnomusicological approaches, the performance and reception of North Indian classical music is said to place an emphasis on visual imagery, connected to gesture and motor activity (Clayton, 2005; Fatone, Clayton, Leante & Rahaim, 2011; Leante, 2014); the role of musical semiotics may also inform visual imagery with music, with Tagg (2013) highlighting the cultural stereotypes of certain instruments implying certain geographical regions of the world, such as the Bagpipes and Scotland. Vuoskoski and Eerola (2015) suggested that different extra-musical information provided before listening to a piece can influence experiences of visual imagery, and in turn affect emotional responses. The link between visual imagery and emotions in music also serves as a basis for guided imagery approaches in music therapy (Burns, 2001; McKinney, Antoni, Kumar, Tims & McCabe, 1997). Juslin and Västfjäll (2008) suggest that visual imagery may be associated with any possible emotional experiences with music, dependent on the idiosyncrasies of the listener. Notably, there are numerous outstanding questions concerned with visual imagery, such as whether there are consistent relationships between categories of visual imagery and musical features or characteristics, how much control a listener has over the visual images experienced, and whether emotional experiences with music result in visual imagery, or vice-versa. One central role of visual imagery may be to support the processing of music in terms of narrative, stories and personas (Margulis, 2017; Robinson & Hatten, 2012); these possible qualities in music may underlie experiences of identifying with, or relating to, a piece of music, and may further be linked to some instances of musical chills responses. However, the mechanism is poorly understood, and remains a complex process to assess causally.

2.1.6 Episodic Memory

Alongside visual imagery, Juslin and Västfäll (2008) highlighted the possible role of episodic memories, referring to a process in which music serves as a retrieval cue for a specific memory in the listener; this memory, intertwined with the music listening experience, may result in an emotional response. Episodic memory often encapsulates memory for autobiographical events, and is distinct from semantic memory, which represents a broader knowledge and recollection of facts of the world that are not personal (Tulving, 1972). Memory has been linked to emotions more broadly, with evidence for the effects of emotional qualities across encoding, consolidation and recall (Levine & Edelstein, 2009; Phelps, 2006); for example, highly emotional events may be encoded differently at the time of their occurrence, experience more effective consolidation, and be more readily accessible to recall.

There exists some research in the context of music that has assessed memory processes, such as memory for pitch and melodies (Halpern & Müllensiefen, 2008; Heaton, 2003), and memory for pieces of music (Bartlett & Snelus, 1980; Krumhansl

& Zupnick, 2013; Schulkind, Hennis & Rubin, 1999). In contrast, fewer studies have assessed the role of episodic and autobiographical memory in emotional responses to music. In earlier work, Baumgartner (1992) asked participants to report their emotional memories evoked by pieces of music; findings indicated that most emotional episodes of musically induced memory were judged as positive, and often these memories referred to social aspects such as romantic interest and interaction, and activities such as being with friends. Furthermore, this study suggested that the affective character of recalled experiences frequently matched the emotional tone of the music. Further research assessed the nature of autobiographical memories in response to popular music, including data on emotion (Janata, Tomic & Rakowski, 2007). Results showed that participants experienced memories with roughly one song from a set of popular music excerpts, and that these experiences resulted in strong emotional responses. Some participants reported happiness, feelings of youth and nostalgia; the presence of nostalgia in episodic memories with music was replicated by Juslin et al. (2008), and in an empirical test of the mechanism by Juslin et al. (2014). Interestingly, nostalgia is a complex emotion (Sedikides, Wildschut, Arndt & Routledge, 2008) that appears to share some qualities with a state known as being moved (Menninghaus et al., 2015); as will be highlighted in **Chapter 3**, these states are further intertwined with some experiences of chills with music. However, given the idiosyncratic qualities of personal, autobiographical memories, the affective consequences are difficult to control and predict; furthermore, the level of overlap between similar processes like visual imagery and memory is not clear.

2.1.7 Musical Expectancy

The process of musical expectations has attracted a great deal of attention in music psychology research, and serves as the seventh mechanism of music and emotion in the BRECVEMA framework. Musical expectations involve processes of anticipation, in which largely implicit predictions are developed by the listener as to how the music will progress (Juslin, 2013); these predictions may simultaneously be directed towards harmonic or melodic development (Narmour, 1990, 1992; Schellenberg, 1996, 1997), rhythmic development (Boltz, 1993; Jones & Boltz, 1989) and the complex interactions between these musical structures (Lerdahl & Jackendoff, 1983). Expectations may be divided into schematic kinds, which are sensitive to, and derived from, musical syntax, and veridical expectations, which are based on an explicit knowledge and familiarity with how a specific piece of music progresses (Bharucha, 1987; Huron & Margulis, 2010; Schubert & Pearce, 2016). These expectations are effortless, unconscious, and pervasive across most listeners within a given musical culture, and may be developed through enculturation and statistical learning processes (Pearce, 2018; Pearce, Ruiz, Kapasi, Wiggins & Bhattacharya, 2010; Pearce & Wiggins, 2006). Importantly, these expectations have historically been considered as central to experiences of musical emotions (Huron, 2006; Meyer, 1956), with a focus on the violation of expectations and incorrect predictions. The emotional impact of violated expectations, especially from a basic emotion perspective, is intuitive in that poor prediction is maladaptive (Huron & Margulis, 2010), and unexpected events may be indicative of threat or urgent events that require attention.

Surprisingly, despite the proclaimed affective impact of musical expectations, there are few studies that focus specifically on the emotional consequences of musical expectations that are primed and subsequently fulfilled, delayed or violated.

Appropriately, earlier work attempted to pin down this expectancy process during music listening, with success across a variety of approaches. Bharucha and Stoeckig (1986) reported faster reaction times in response to target chords harmonically related to prime chords, as opposed unrelated chord pairs; in neurophysiological work, the perceptual processing of musical expectations has been evidenced (Besson & Faïta, 1995), with consistent results found for certain event-related potentials such as the early right anterior negativity (Carrión & Bly, 2008; Koelsch & Friederici, 2003; Koelsch, Kilches, Steinbeis & Schelinski, 2008), and the N5 (Poulin-Charronnat, Bigand & Koelsch, 2006); these rapid processes reflect musical syntax processing and harmonic integration respectively. With regards to emotion and affective experiences, Bigand, Parncutt and Lerdahl (1996) linked musical expectancy to perceived tension in music, which Krumhansl (1997) additionally linked to perceived emotional moods in music; Steinbeis, Koelsch and Sloboda (2006) found evidence for heightened skin conductance responses to harmonic violations, alongside ratings of emotional impact and intensity. More recently, Egermann, Pearce, Wiggins and McAdams (2013) found that a probabilistic model of musical expectancy predicted emotional responses to music in live concert settings. Crucially for the subsequent literature review on musical chills, musical expectancy may be a significant mechanism across musical chills experiences, and is implicated in existing correlational research on the phenomenon.

2.1.8 Aesthetic Judgment

The final, most recent mechanism proposed for emotions induced by music is that of aesthetic judgment (Juslin, 2013). This is a complex, perhaps vague, collection of processes that interact with all other proposed mechanisms in the framework. The topic of aesthetic judgment and appraisal reflects more conscious, socio-culturally grounded decision-making processes, which whilst essential for understanding any affective engagement with music, is beyond the scope of the current research project and its focus on theoretical propositions for musical chills; for this reason, aesthetic judgments will be summarised briefly, whilst acknowledging the breadth and extent of aesthetic psychology work in which these proposed processes have their roots.

In including aesthetic judgment as a final mechanism of musical emotions, Juslin (2013) denotes a simplified description of the judgment process: Firstly, the object of an experience is understood or pre-classified by an observer as 'art' through processing of perceptual, cognitive and emotional inputs, the latter derived from the other emotion mechanisms discussed; secondly, a set of aesthetic criteria are utilised by the observer, ranging from assessments of beauty, skill, novelty, style, message and expression; finally, an aesthetic judgment is produced which, depending on the level of positivity or negativity of the outcome, may result in liking or disliking a piece of art, or in more intense circumstances result in emotional responses. This description is derived from a tradition of modelling aesthetic judgments and emotion, such as an earlier attempt from Leder, Belke, Oeberst and Augustin (2004); in this approach, low-level and high-level processes interact with the pre-classification of an object as 'art', previous experiences, current context of engagement, and the prevailing affective state that feeds into all steps of the model. More recently, a similar tradition of model development was reported in relation to enjoying visual art (Pelowski, Markey, Forster, Gerger & Leder, 2017). These results represent a complex set of processes, explicit and implicit, that are difficult to empirically test. However, for present purposes, aesthetic judgments mainly describe a variety of subjective criteria imposed upon an art object by individuals, and can vary from assessments of beauty, how and what art expresses, originality, skill and virtuosity, and an underlying artistic message (Juslin, 2013). Furthermore, these criteria are likely to be hierarchically arranged in terms of their importance, and that this organisation will differ from person to person (Juslin & Isaksson, 2014; Juslin, Sakka, Barradas & Liljeström, 2016). This process of subjective judgment is crucial to keep in mind when considering the induction of musical emotions, and research is yet to fully integrate theories of induction processes not specific to music, and the subjective judgments that are framed differently depending on the aesthetic engagement taking place.

2.2 Limitations

Whilst the psychological mechanisms of music and emotion comprising the BRECVEMA framework have provided numerous routes for further investigation, there are existing limitations to consider. For instance, there is little understanding as to how these mechanisms may interact with each other to produce predictable emotional responses. Additionally, it is unclear how various causal mechanisms of music and emotion interact with broader musical engagement contexts, and the characteristics of the individual (North & Hargreaves, 2008). Finally, whilst the newly added aesthetic judgment mechanism attempts to accommodate other routes to emotional experience with music, the mechanism is vague, not a distinct psychological process like other mechanisms, and currently inadequate in its exploratory power. This limitation is most clear when considering another psychological concept increasingly linked to musical engagements, and one that is pertinent to the coming discussion and assessment on musical chills, namely empathy.

2.2.1 Empathy

Empathy is treated as a complex construct in the broader psychological literature, with numerous conceptualisations proposed (Cuff, Brown, Taylor & Howat, 2016); at a holistic level however, empathy may designate the behaviours and feelings we experience in response to another's situation or emotional state. One consistent distinction made in discussions on empathy is that between cognitive and affective empathy. Cognitive empathy refers to understanding, simulating, and responding to another person's emotional experiences, whereas affective empathy is often described as an emotional experience elicited by a stimulus, such as another person's experience or state. Crucially, in the current context, empathy is distinguished from contagion processes, mainly because contagion is largely characterised by automaticity (Laurence, 2007), whereas empathy is often understood here as a more conscious process, in which we may imagine and relate to how a person is feeling (Clarke et al., 2015), and respond in culturally appropriate ways (Zickfeld, Schubert, Seibt & Fiske, 2017); however, it is important to note that emotional contagion may also be approached as a low-level variation of affective empathy.

Empathic processes have recently been implicated in numerous musical contexts, with a common focus on music making and group musical interactions. Regarding broader social interaction and cooperation, interpersonal entrainment appears to emphasise affiliative behaviours (Hove & Risen, 2009; Launay, Dean & Bailes, 2013). As highlighted in the rhythmic entrainment section, joint music playing and synchronising may increase prosocial behaviours (Cirelli et al., 2014; Kirschner & Tomasello, 2009; 2010). In addition to this, Rabinowitch, Cross and Burnard (2013) suggested that carrying out regular musical group interactions across a school year resulted in higher emotional empathy scores for the children involved, compared to a control group.

Despite this growing research, there is less work linking empathy directly to emotional responses to music, although some evidence suggests that there is a relationship. For example, Egermann and McAdams (2013) highlighted that trait empathy might mediate the relationship between perceived and felt musical emotions in listeners; trait empathy has further been linked to the enjoyment of sad music (Eerola, Vuoskoski & Kautiainen, 2016), and intense emotional experiences with music (Vuoskoski, Thompson, McIlwain & Eerola, 2012). Empathic and social processes are further highlighted in numerous accounts of strong experiences with music, describing instances of feeling understood by music, feeling one with music, and identifying one's self and identity within a piece of music (Gabrielsson, 2011). Recent work on pleasure and motivations for music listening also places an emphasis on feelings of kinship and social connectedness (Saarikallio et al., 2018). It seems intuitive that empathic processes may underlie many affective engagements with music, with an immediate example being the prevalence of lyrics in contemporary popular music, and their role in the overall emotional expression of the piece (Ali & Peynircioglu, 2006; Lamont, 2011; Lippman & Greenwood, 2012). Crucially, lyrics, as a characteristic of most current music, is rarely encapsulated by proposed underlying mechanisms of musical emotions. Equally important is that, with regards to the musical chills phenomenon, there is evidence that empathy may play a prominent role in some theories of the response, to be discussed at length in **Chapter 3**. If the role of empathy in musical chills can be supported, this has substantial implications for existing formulations of music and emotion mechanisms, including the BRECVEMA framework.

2.3 Summary

Emotional experiences with music appear to be, like emotions more broadly, contingent on a wide variety of factors, ranging from the listening context and individual differences, to qualities and characteristics of the music. Notably, extensive research has resulted in numerous proposed mechanisms of music and emotion, often associating an emotional response to musical features. These mechanisms encapsulate processes of anticipation, expectation and surprise, entrainment of biological signals to external rhythms, imagery, and memory. Not all causal mechanisms are intertwined with musical characteristics, such as memories and conditioning effects. However, there remains a substantial limitation to understanding musical emotions, such as how the music engages with conscious aesthetic judgments that are shaped by socio-cultural contexts; additionally, the proposed mechanisms do not encapsulate important, common features of current music such as lyrics, which may be closely associated with empathic and social processes linked to emotion (Clarke et al., 2015). The alternative multiple components processing model (Scherer & Coutinho, 2013; Scherer & Zentner, 2001) differs slightly in the mechanisms proposed, particularly in relation to empathy, although similar broader issues persist.

The BRECVEMA framework (Juslin, 2013; Juslin & Västfjäll, 2008) offers a testable set of hypotheses, but more importantly, offers a useful, mechanistic context with which to situate theory development and empirical investigations of the musical chills phenomenon. As a result, the following review and studies presented on chills will be contextualised and framed in relation to the broader level of psychological mechanisms of music and emotion (Juslin, 2013). This explicit context not only shapes the current project, but plays a vital role in allowing investigations of musical chills to reflexively inform both the broader emotion science literature, and music and emotion research.

3. Musically Induced Chills

Beyond the apparent efficacy of music to express, communicate and induce emotions, engaging in music listening can also result in particularly strong or intense emotional experiences. Earlier work into peak experiences by Maslow (1964) suggested that aesthetic engagements, alongside religious activity, may be effective elicitors of strong emotions. In more recent, extensive work involving close to a thousand open-ended responses (Gabrielsson, 2011), a rich picture regarding the variety of strong emotions that can occur during music listening has been developed. In a broad descriptive system that describes the accounts of strong emotions with music at a holistic level, numerous main factors were established, referring to perception of musical qualities, bodily sensations and other senses, changes in cognition and associations with memories, existential and transcendental aspects of religious experience, and personal or social aspects of the experience, such as feeling liberated, reaffirmation of identity, and connecting with other audience members or performers through the musical experience. Additionally, long-term effects of strong musical experiences have been suggested to have a positive impact on eudaimonic well-being and life satisfaction (Schäfer et al., 2014). However, of these factors, the description of physical reactions and sensations has continued to receive sustained attention in music and emotion research, with a focus on the phenomenon of chills in response to music.

3.1 Musical Chills

3.1.1 Terminology and Definitions

In the prevailing literature, chills are generally considered to be a psychophysiological response to music that may include goosebumps, shivers down the spine, and subjective tingling sensations perceived by the listener. However, there are variations in the terminology, definitions and conceptualisations employed in the field that need to be delineated in the current context.

Firstly, across existing literature there are numerous terms utilised that may refer to the same psychophysiological experience; whilst '*chills*' is perhaps the most commonly used descriptor (Grewe, Nagel, Kopiez & Altenmüller, 2007; Panksepp, 1995; Rickard, 2004), *thrill* has also been utilised (Goldstein, 1980; Konečni, 2005), and even *skin orgasms* proposed (Panksepp, 1995). *Frisson*, the French word for shiver, is also a suggested term for the response (Huron & Margulis, 2010; Kovacevich & Huron, 2019), that describes an experience closely related to musical surprise, and one of pleasant tingling sensations accompanied by piloerection. The labels ascribed to this psychophysiological experience have issues embedded in the connotations that they communicate; chills may be confused with fear and 'chilling' horror; thrills indicate an exhilarating, high arousal response such as riding a rollercoaster, and does not relate to the underlying thermoregulatory aspects of both goosebumps and shivers; finally, frisson has the advantage of subverting the social and cultural connotations of other terms, but is in danger of being too broad of a conceptualisation, or of ascribing too much significance to elements of surprise. In the current context, the experience of tingling, goosebumps and shivers will be referred to as chills for two reasons: Firstly, it is the most commonly used label in existing literature; secondly, in the only investigation that asked for participants' preferred term, Panksepp (1995) found that chills were preferred over thrills. However, as will be shown through this review of the literature, labels such as chills and thrills may in fact be useful in describing distinct experiences that share psychophysiological characteristics.

Secondly, as might be expected, the variability across definitions of the response runs analogous to that of terminology: Goldstein (1980), citing the Oxford English Dictionary, described a thrill as "*a subtle nervous tremor caused by intense emotion or excitement (as pleasure, fear, etc.), producing a slight shudder or tingling through the body*" (p. 126); this definition was further utilised by Grewe et al. (2007, p. 297). Sloboda (1991) described one type of thrill as "*a pleasant physical sensation often experienced as a 'shiver' or a 'tingle' running from the nape of the neck down the spine*" (p. 110). Panksepp (1995) referred to the chills response as a "*spreading gooseflesh, hair-on-end feeling that is common on the back of the neck and head and often moves down the spine, at times spreading across much of the rest of the body*" (p. 173); and Guhn, Hamm and Zentner (2007) noted chills as a "*sudden, arousing reaction that is accompanied by goose bumps, shivers or tingles in the spine*" (p. 473). Across these nuanced and varied definitions, consistent aspects include the physical elements of goosebumps, shivers or tingles, and the arousal of emotion or pleasure; consequently, a working definition for the current dissertation is that chills are a *subjective emotional experience accompanied by goosebumps, shivers or tingling sensations.*

3.1.2 Physical, Psychophysiological and Neurophysiological Characteristics

Physical Responses

The physical elements and concomitants of musical chills experiences have been studied to an extent, such as surveying what physical sensations are experienced by listeners, and where these sensations are localised and felt in the body. Goldstein (1980) found that tingling sensations were often reported as occurring in the upper spine, back of the neck, shoulders and scalp. In contrast, Craig (2005) suggested that most reported chills experiences occurred in the arms, hands and fingers, although the face, head and neck were again highlighted. Progressing from self-report data however, some attempts have also been made to observe bodily activity such as goosebumps in real time, such as during a music listening episode. One of the first studies to attempt this was carried out by Craig (2005), who asked participants to listen to pieces of music, whilst having one arm extended underneath a curtain that divided the participant and investigator; as participants reported chills experiences by raising a finger on this extended arm, the experimenter observed whether there was any visible goosebumps response. Interestingly, this approach proved relatively successful, although a salient finding was that roughly 50% of reported chills experiences showed no visible goosebumps. More recently, technological advancements have seen the development of a ‘Goosecam’ instrument, a small video recording device that is attached to a participant’s forearm during an experiment (Benedek & Kaernbach, 2011; Benedek, Wilfling, Lukas-Wolfbauer, Katzur & Kaernbach, 2010; Wassiliwizky, Jacobsen, Heinrich, Schneiderbauer & Menninghaus, 2017a); through transforming the video data, the Goosecam has been used to quantify the magnitude of any goosebumps response, providing a more statistically robust approach. Like Craig (2005), Benedek & Kaernbach (2011) found, using the Goosecam, that roughly half of the reported chills experiences showed no detectable goosebumps; this may be a result of the goosebumps response occurring in different areas of the body, or due to differences in the chills experience across participants, and how they conceptualise or understand the phenomenon.

Psychophysiological Responses

Alongside assessing the physical and bodily activity that might accompany chills experiences, research has attempted to characterise the corresponding patterns of psychophysiological activity.

One of the first studies to focus on chills alongside physiological measures such as skin conductance, heart rate and skin temperature, was carried out by Rickard (2004). In this study, participants listened to pieces of music, some selected by the experimenter, and some selected by the participant as being emotionally powerful. Notably, the emotionally powerful music, when compared to other treatments, elicited significantly greater skin conductance responses, a physiological signal that is sensitive to emotional arousal and governed by the sympathetic branch of the central nervous system (Hodges & Sebald, 2011); moreover, the emotionally powerful music resulted in more chills reports from participants. However, the author suggested that increases in skin conductance were rarely accompanied by chills reports from participants, when comparing the responses over time. In contrast, several studies on musical chills have since utilised skin conductance to effectively validate real-time self-reports of chills experience during listening, collected via button presses (Benedek & Kaernbach, 2011; Egermann et al., 2011; Grewe et al., 2007; Grewe, Kopiez & Altenmüller, 2009; Sutherland et al., 2009). Furthermore, Guhn et al. (2007) found that musical chills experiences were accompanied by higher skin conductance responses, after controlling for potential inter-individual differences in physiological responsiveness (Khalfa et al., 2002).

Although skin conductance, as a measure of emotional arousal and intensity, has been the most frequently assessed physiological index of musical chills experiences, other studies have focussed specifically on aspects such as heart rate and pupil dilation. Multiple physiological measurements were investigated by Salimpoor et al. (2009), looking at reported experiences of low pleasure, high pleasure, and chills during music listening; results showed that chills were accompanied by significantly higher levels of skin conductance, increased heart and respiration rate, and significant decreases in skin temperature and blood volume pulse amplitude, when compared to neutral experiences. Regarding heart rate, it was suggested that aesthetic chills in response to music or film were accompanied by significant increases in heart rate (Benedek & Kaernbach, 2011; Sumpf, Jentschke & Koelsch, 2015). More recently, Laeng et al. (2016) showed that self-reports of chills experiences in response to music were often accompanied by significant increases in pupil dilation, suggesting an experience of higher emotional arousal.

However, mirroring variations already highlighted regarding definitions and terminology surrounding chills, there are inconsistencies in results across psychophysiological work. Whilst skin conductance is the most consistently utilised marker of chills experiences (Benedek & Kaernbach, 2011; Grewe et al., 2007; Grewe et al., 2009; Salimpoor et al., 2009), the measure has not always correlated with chills (Blood & Zatorre, 2001; Rickard, 2004); additionally, skin conductance responses during chills might differ depending on sensory modalities of stimuli (Grewe, Katzur, Kopiez & Altenmüller, 2010), whether music is participant-selected or experimenter-selected (Mori & Iwanaga, 2014), and whether skin conductance is assessed during objective goosebumps measurements or self-reports of chills (Wassiliwizky, Koelsch, Wagner, Jacobsen & Menninghaus, 2017b). For heart rate, increases corresponding to chills have been reported (Mori & Iwanaga, 2017; Salimpoor et al., 2009; Sumpf et al., 2015), yet Guhn et al. (2007) found no changes. For respiration rate, increases were reported by Salimpoor et al. (2009), yet no changes were found by Mori and Iwanaga (2017). Finally, for skin temperature, decreases during chills have been suggested (Salimpoor et al., 2009), but elsewhere no changes were found (Blood & Zatorre, 2001; Craig, 2005).

Neurophysiological Responses

A further avenue of work on the chills phenomenon has employed various brain imaging techniques, to assess patterns of brain activity change during the response. One of the first examples is provided by Blood and Zatorre (2001), using a positron emission tomography (PET) scan method to assess changes in regional cerebral blood flow volumes in different areas of the brain during chills. Participants listened to self-selected chills music excerpts, experimenter-selected control excerpts, and experienced two baseline conditions (noise and silence); after listening, participants could then rate the 'chills intensity' of the listening experience, a measure with which cerebral blood flow levels were correlated. The results from the study highlighted numerous positive correlations between ratings of chills intensity and activity in the left ventral striatum, right orbitofrontal cortex, anterior cingulate cortex, thalamus and supplementary motor area. Furthermore, increases in chills intensity ratings were linked to decreases in activity in the bilateral amygdala, left hippocampus, ventromedial prefrontal cortex and various cuneus and precuneus regions. Activity in these regions is consistent with experiences of pleasure and euphoria (Becker et al., 2019; Berridge & Kringelbach, 2015; Gottfried, 2011; Pfaus, Damsma, Wenkstern & Fibiger, 1995; Richards, Plate & Ernst, 2013; Schilström, Svensson, Svensson & Nomikos, 1998), with regions such as the ventral striatum being implicated in the processing of reward, hedonic impact, learning and motivation (Liu, Hairston, Schrier & Fan, 2011).

Following the links between musical chills and rewards circuitries in the brain, Salimpoor, Benovoy, Larcher, Dagher & Zatorre (2011) extended the PET methodology, combining with fMRI scans to assess dopamine release activity during experiences of musical pleasure and chills; various dopaminergic mechanisms in the brain underlie regions such as the ventral striatum, with dopamine functioning as a neurotransmitter in these reward-related pathways. Through PET data, the authors found that in pleasurable music conditions compared to neutral music conditions, there was increased endogenous dopamine transmission in the bilateral dorsal and ventral striatum, with highest increases found in the right caudate and right nucleus accumbens (NAcc), a hedonic hotspot in the mesolimbic reward pathway (Castro & Berridge, 2014). However, the study also assessed the temporal dynamic of dopaminergic activity alongside self-reported chills responses from participants whilst listening. With anticipation (15 seconds before chills report) and peak epochs (onset of chills) defined, it was reported that hemodynamic activity in regions showing dopamine release increased in the NAcc during peak epochs, but for the anticipation epoch these increases were mostly found for the right caudate. It is important to note that hemodynamic activity around regions showing dopamine release was not consistent throughout the excerpts being listened to, and was mainly confined to the anticipation and peak epochs of musical chills, suggesting anatomically distinct activity during these responses.

These findings from Salimpoor et al. (2011) provided evidence for the role of dopaminergic activity and the mesolimbic reward system in musical chills experiences, and highlighted the experience of anticipation leading up to chills responses. Interestingly however, similar recent work on aesthetic chills in response to spoken poetry found a similar anticipation and peak epoch pattern of response (Wassiliwizky et al., 2017b), labelled by the authors as a pre-chill and chills response. Notably, this study reported that the pre-chill period was characterised by increases in NAcc activity compared to the actual onset of chills, contradicting findings from Salimpoor et al. (2011).

Most recently, an attempt at assessing the causal interactions between dopaminergic activity and musical chills was carried out by Ferreri et al. (2019). In this study, dopaminergic synaptic availability, or the capability of synapses to receive or transmit dopamine, was manipulated through the administration of either a dopamine precursor called levodopa, or a dopamine antagonist called risperidone; a placebo condition was also included. It was predicted that levodopa, as it is transformed into dopamine quickly by the brain to enhance synaptic event-related responsivity, would result in increased musical pleasure; in contrast, risperidone interferes with dopaminergic transmission by binding to various receptors, which was predicted to reduce musical pleasure. Results from these methods indicate that participants spent more time reporting chills overall whilst listening when administered with levodopa as opposed to risperidone; similar results were found for broader ratings of musical pleasure, although the administration conditions resulted in little difference for skin conductance levels. These encouraging results are a crucial step forward into causal manipulations of chills experiences, although the neurochemical relationships tested remain highly complex, and it is unclear as to the precise role of dopamine release in the response, especially given the numerous agonistic and antagonistic interactions between neurochemicals and neurotransmitters. Despite this however, the existing literature attempting to characterise the experience of musical chills seems to converge at the level of chills reflecting moments of peak pleasure, and of high emotional arousal.

3.1.3 Scope and Related States

Given the variations across terminology, definitions and some psychophysiological characteristics of chills, it is not surprising that there exists an overarching issue of scope and framing of the phenomenon. There are currently outstanding questions regarding musical chills and aesthetic chills more broadly, such as how broad or narrow the conceptualisation of the response should be, what criteria would be suitable for qualifying a chills experience, and how the phenomenon can be quantified in a meaningful way. In the extant research, only objective evidence of goosebumps has been found corresponding to reports of chills, yet many reports of chills are not accompanied by this physical response (Benedek & Kaernbach, 2011; Craig, 2005). There are also inconsistencies regarding the psychophysiological activity patterns accompanying chills, particularly in the case of heart rate and skin temperature. Finally, musical chills have been linked to increases in dopaminergic activity in the NAcc, with preceding anticipatory phases linked to increased right caudate activity (Salimpoor et al., 2011); again however, some contradictions arise, with higher levels of activity change found in the anticipatory epoch compared to chills onset in response to poetry (Wassiliwizky et al., 2017b).

Beyond the relative consistency issues highlighted in the literature, there are larger problems in that shivers and tingling sensations have yet to be objectively attributed to any aesthetic chills response. Shivers are sometimes reported by participants, but these descriptions may be little more than linguistic approximations of phenomenological sensations, as there is no current evidence of muscular contractions (in the abdominal region for example) occurring during chills reports. Shivering may also be physiologically distinct from goosebumps, such that goosebumps are linked to sympathetic nervous system activity and the fight-or-flight response (Darwin, 1872; Frijda, 1986), whilst shivering is less so (Haman & Blondin, 2017; Jänig, 2009; Romanovsky, 2007). Further evidence of a distinction between goosebumps and shivers is that whilst both are symptoms of fevers or seizures, the co-occurrence of the two responses is significantly rare (Stefan, Feichtinger & Black, 2003; Stefan, Pauli, Kerling, Schwarz & Koebnick, 2002); it is important to note however that shivers have been linked to emotions and experiences of stress (Briese, 1995; Briese & Cabanac, 1991), and the physical reaction may still be implicated in strong emotions. Whilst tingling sensations are also reported by participants, and are included alongside shivers and goosebumps in a working definition of chills, these sensations are highly elusive and there is yet to be an appropriate methodology of objectively quantifying this experience; this a primary objective of some medical fields given that tingling can be a symptom of numerous illnesses and conditions (Tihanyi, Ferentzi, Beissner & Köteles, 2018).

Besides the lack of evidence for several physical indices of chills, there is also the issue of the adjacency of the experience to other related states, such as tears or crying, and a recently formalised experience known as the autonomous sensory meridian response (ASMR).

Tears and Crying

Goldstein (1980) originally suggested that the thrills experiences, commonly reported in response to music, could also be accompanied by tears or weeping, and sensations of feeling a lump in the throat; similar results were presented by Laeng et al. (2016). More recently, two studies assessed and compared experiences of tears and chills experiences. In a study of music listening, Mori and Iwanaga (2017) assigned participants to a chills group or tears group for an experiment, listening to self-selected and experimenter-selected music and pressing a button when experiencing either chills or tears (respective to each group); physiological data were also collected, included respiration rate, skin conductance, and electrocardiogram measurements. Results suggested that the physiological activity underlying reports of chills and tears were broadly comparable, although a difference was found for the skin conductance response, with the response increasing only during reports of chills. Another difference was found for respiration rate, with decreases found for tears experiences, but not for chills; this contrasts with scant earlier research into tears that found accompanying increases in skin conductance and faster breathing (Gross, Fredrickson & Levenson, 1994; Kraemer & Hastrup, 1988). Furthermore, music that elicited chills was perceived to be happier than sad, whereas tears-inducing music was judged as sadder. The authors interpreted these small differences as a possible distinction between two types of peak emotional experience with music, with chills characterised as a high arousal response, and tears as a calming response with cathartic functionality.

However, a second study focussed on the concurrence of both chills and tears in response to emotional film scenes (Wassiliwizky et al., 2017a). Using a Goosecam to detect goosebumps responses, and self-report button presses to capture instances of tears, psychophysiological characteristics and concurrence of the two experiences were analysed. Results showed firstly that 58.7% of goosebump reactions occurred simultaneously with self-reported tears experiences, sometimes with goosebumps preceding tears, and sometimes vice-versa, although no order effects were observed. Regarding the psychophysiological qualities, an interesting pattern was found for heart rate, skin conductance and both corrugator and zygomaticus muscle activity detected through facial electromyography; in these cases, an observable increase in physiological arousal was found when moving from control experiences to piloerection, to tears, and then to instances of piloerection and tears together. Taken together, it is unclear as to why the two studies reported diverging findings, although there are two possibilities: Firstly, Mori and Iwanaga (2017) collected button press reports of chills in contrast to objectively capturing goosebumps (Wassiliwizky et al., 2017a), suggesting that participants' conceptualisation of chills may not align with goosebumps responses, and might confound the comparability of results; secondly, Mori and Iwanaga (2017) used music in contrast to film (Wassiliwizky et al., 2017a), possibly resulting in qualitatively distinct experiences and underlying psychological mechanisms, a possibility of great interest for the current chapter and overall dissertation. Regardless, it is currently unclear as to the exact relationship between chills and tears experiences with aesthetic stimuli, although it appears at least that some chills responses may be characterised by co-activation of closely related states.

Autonomous Sensory Meridian Response

Apart from tears, a second related state is the ASMR response. Although ASMR has only recently attracted attention in psychological research, the experience is likely to have been common in a certain sample of the population for many years, evidenced by a blossoming industry of videos and digital content on YouTube, Twitch and other social media platforms specifically designed to elicit ASMR. In one of the first scientific studies, Barratt and Davis (2015) explored video triggers of the experience, and reasons for pursuing the response. Results from this exploratory approach highlight that ASMR was characterised by participants as a positive experience of tingling originating towards the back of the scalp, progressing down the spine and occasionally to the shoulders. In terms of motivation, 98% of 475 participants sought out ASMR as an opportunity for relaxation; concordantly, ASMR was claimed to help participants get to sleep, or to deal with stress. With regards to video triggers, the four most common categories were whispering, personal attention, 'crisp' sounds and slow movements, suggesting that the interaction between auditory and visual stimulation is a strong basis for the experience; however, there was notable inter-individual variation when reporting triggers. Progressing from this, further work investigated individual differences in relation to ASMR experiences; Fredborg, Clark and Smith (2017) suggested that those who experience ASMR score higher on the openness to experience and neuroticism personality traits compared to those who do not. Furthermore, Smith, Fredborg and Kornelsen (2017) assessed activity in the default mode network of the brain with fMRI scanning, and found that compared to those who do not experience ASMR, participants who experience the response showed reduced connectivity between frontal lobes and sensory attentional regions in the precuneus and parietal cortex; the authors theorised that this decreased connectivity may result in a lessened ability to inhibit sensory-emotional experiences. Finally, Cash, Heisick and Papesh (2018) provided participants different instructions before presenting audio clips effective at eliciting ASMR; these instructions stated that the following audio clips were either effective or ineffective at eliciting ASMR, to assess how this information affected the experiences of participants. Participants were further split into a naïve group or ASMR group, comprised of psychology students and frequenters of an online forum for ASMR respectively. Notably, the instructions affected naïve participants, such that ASMR was less frequent when told that the stimuli were ineffective, and vice-versa; this was not the case for those in the ASMR group.

Given the overlap in reported physical sensations between chills and ASMR, comparisons between the two phenomena are natural. In a recent review (del Campo & Kehle, 2016), it was suggested that ASMR and chills were related phenomena, citing a study by Grewe et al. (2010) that found reports of chills in response to a variety of visual, auditory and tactile stimuli. However, these similarities are often refuted by those who experience ASMR (Collins, 2012; Higham, 2014), and there is yet to be any real evidence beyond reported physical sensations that suggests that the two phenomena belong to the same construct; on the other hand, recent physiological work reported increases in skin conductance corresponding to reports of ASMR (Poerio et al., 2018), so exploring the extent of the relationship between chills and ASMR may be a useful future endeavour.

3.1.4 Summary

Keeping in mind the consistencies and contradictions in psychophysiological or neurophysiological characteristics of chills, and potential relationships with tears and ASMR that are not well understood, it is important to state that whilst a working definition of chills is presented here, the conceptualisation and framing of the phenomenon has not been explicitly explored. This may lead to several possibilities and explanations for most musical chills research linking the response to various features and characteristics within the music, to individual differences of the listener, and to various listening situations and contexts. In the following review of musical chills literature and theory, these conceptual issues surrounding the chills construct are far from trivial, and have potentially substantial implications for existing and future research, especially when considering the possibility that chills might not reflect a unified psychological construct.

3.2 Chills and Musical Features

Aesthetic experiences are not a novel object of investigation, although it is only recently that the philosophical debates of aesthetics have often intertwined with the empirical approaches of psychology (Pelowski et al., 2017). Intense or peak aesthetic experiences were studied by Panzarella (1980), collecting reports regarding experiences with music or visual art. Through a content analysis and subsequent factor analysis of the reports, four main factors were proposed, one of which was labelled *motor-sensory ecstasy*, referring to physical changes including heart rate, breathing, posture, shivers and tingles. Interestingly, these types of experiences were more frequently reported in instances of musical engagement as opposed to visual art.

Indeed, whilst investigating the experience of ecstasy, Laski (1961) found that although a wider variety of triggers exist for ecstatic peak experience, music appeared as the most frequently mentioned kind of art. In the first empirical assessment of the chills response, Goldstein (1980) also noted that music was particularly effective in eliciting chills. In this first investigation, Goldstein (1980) also reports that the pattern of chills experiences seemed to reflect obvious peaks and troughs in the overall musical contour, which although a vague and unsystematic observation, highlighted the possible association between chills responses and certain moments or features in music.

Musical Structure

In research on musical chills, establishing links and correlations between the experience and musical structure and psychoacoustic parameters is the most common line of enquiry. Early research by Sloboda (1991) asked participants to retrospectively highlight pieces of music that had elicited a variety of physical reactions, and to pinpoint as accurately as possible the moment in the music that elicited the response. Across numerous physical reactions reported, shivers down the spine were most common, followed by laughter, feeling a lump in the throat, and tears. Using information provided regarding more specific epochs or moments in the music associated with these reactions, shivers were suggested to be linked to new or unprepared harmony, and sudden dynamic or textural changes; tears were instead associated with melodic or harmonic sequences, and melodic appoggiaturas. However, it is worth noting that of roughly 30 passages linked to shivers or tears, eight of these were reported to evoke both reactions, reflecting recent evidence for the simultaneous experience of piloerection and tears (Wassiliwizky et al., 2017a).

Following the initial work by Sloboda (1991), Panksepp (1995) carried out numerous experiments, with findings ranging from the demographic information of those experiencing chills, to rudimentary time-series data linking real-time reports of chills to moments in musical stimuli. With regards to specific musical features, one piece of music by Pink Floyd seemed to show notable convergence in terms of when chills were experienced across listeners; importantly, these chills occurred alongside a sudden dynamic change from very quiet to very loud, with the introduction of a higher melody in the human singing voice. However, in another piece by Air Supply that seemed to be effective at eliciting chills, no clear pattern emerged that connected the experience with salient structural features in the music. Panksepp (1995) highlighted that beyond a crescendo, sad or bittersweet music could be the most effective elicitor of chills.

Developing from these findings, Grewe et al. (2007) attempted to extend the correlational approach to musical chills by accounting for issues of chills validation; this was achieved by combining button press reports of chills whilst listening, and concurrent skin conductance measurements. Through analysing the chills response patterns to various pieces of different styles, numerous musical features were suggested to be linked to the experience, including the entrance of a new instrument or voice, changes in volume, melody, harmony, theme or motive, rhythm, and the contrast of two voices. Similar work was carried out by Guhn et al. (2007), who found that musical passages that elicited chills were all from slow movements, were characterised by alternations between solo and accompaniment, and contained sudden or gradual volume increases. These results are more expansive than previous studies, and suggest that there is plethora of structural and musical features that may elicit the chills response in different listeners. Although the inclusion criteria for chills in these investigations was robust in contrast to previous research, the use of skin conductance measurements potentially remains problematic for two reasons: Firstly, there are large individual differences in skin conductance behaviour (Nyclicek et al., 1997; Khalfa et al., 2002), with some listeners likely to be categorized as ‘non-responders’; secondly, whilst skin conductance and goosebumps may reflect sympathetic nervous system activity, shivers may not (Haman & Blondin, 2017; Jänig, 2009; Romanovsky, 2007), and so depending on the phenomenology of the chills experience, skin conductance may not be a consistently adequate measure.

Psychoacoustic Parameters

With regards to characteristics of the music, psychoacoustic properties have received little attention in chills research, although it is worth highlighting some existing findings. Panksepp (1995) suggested, without an accompanying psychoacoustic analysis, that solo voices or instruments sounding sustained high-frequency notes may be effective qualities. Guhn et al. (2007), through a musicological analysis of chills passages in their musical stimuli, suggested that most passages could be characterised by an expansion in the frequency range, with sometimes a concurrent introduction of lower pitched bass lines and higher register melodic lines. Only a handful of studies have assessed psychoacoustic parameters with audio analysis techniques. For example, Halpern, Blake and Hillenbrand (1986) investigated negative chills experiences in response to abrasive or highly unpleasant sounds, such as nails scratching down a blackboard. Notably, the unpleasantness of these sounds could often be attributed to high levels of spectral energy in the frequency band of 3000 Hz to 4000 Hz; consulting the Fletcher-Munson curves of human hearing (Fletcher & Munson, 1933), we are most sensitive to sounds within this frequency range, and so it is unclear whether the frequencies in this range were linked to unpleasantness, or whether the results were mediated by higher levels of perceived loudness. Work by Grewe et al. (2007) assessed various psychoacoustic parameters and how they correlate with chills responses during a piece of music. Results showed that increases in loudness and auditory roughness were significantly correlated with the onset of chills reported by participants; additionally, spectral sharpness and flux increases seemed to correlate with moments in the music roughly a second before the reported onset of a chills experience. Nagel, Kopiez, Grewe and Altenmüller (2008) also focussed on psychoacoustic analyses of chills moments in music, suggesting that loudness increases in the frequency range of 920 Hz and 4400 Hz, and increases in auditory roughness, were correlated with reports of chills experiences.

Summary

To summarise, existing chills research has mainly focussed on the possible relationships between specific aspects of a piece of music, such as structural changes in dynamics or harmonic content, and psychoacoustic parameters of the audio being listened to. There is perhaps one consistent finding across most of the existing literature, which is the association between sudden dynamic changes, crescendos, and the chills response (Grewe et al., 2007; Panksepp, 1995; Sloboda, 1991). In the context of music and emotion mechanisms, the correlational findings often appear to implicate brain stem reflexes and musical expectancy processes (Juslin & Västfjäll, 2008).

Despite some consistent results, there are also examples of highly effective chills-inducing music with little consistency or convergence of chills responses, and few salient structural features attributed to them (Panksepp, 1995); this reflects a broader, observed inconsistency inter- and intra-individually, such that music and structural features linked to chills are not effective for all listeners, and not consistently effective within some listeners (Grewe et al., 2007). Therefore, inserting a sudden dynamic change into a piece of music might be unlikely to elicit chills reliably within and across listeners, and as with any emotional experience with music, individual differences, and the wider context will contribute importantly to the chills response.

3.3 Chills, the Listener and the Situation

In acknowledgement of these prevalent issues and complexities in music and emotion research, some musical chills research has taken a slightly different approach, and framed the phenomenon in the context of individual differences, and in some cases the listening situation.

Individual Differences

It has been shown that with various aspects of musical engagement, aspects of the individual listener are an important factor; in the case of musical chills and individual differences, investigating the role of personality traits is perhaps the most common approach. As is the case with a variety of emotional responses to music, there appear to be striking individual differences in how often chills are experienced with music (Grewe et al., 2009), and whether some listeners experience them at all; although there is no clear picture of how prevalent musical chills could be, some researchers have suggested that as much as half of the general population may be non-responders (Huron & Margulis, 2010). Naturally, personality traits of listeners may influence the frequency and experience of musical chills. In a study utilising the big five model of personality (McCrae & John, 1992), focussing on the five traits of conscientiousness, agreeableness, neuroticism, openness to experience, and extraversion, McCrae (2007) suggested that of the various rating items included in the NEO-PI-R personality inventory, a specific item related to experiencing chills with aesthetic stimuli was the best indicator of openness to experience; in addition, this link was proposed to be universal through consistent findings across various translations of the inventory, although this does not encapsulate the potentially complex, multifaceted conceptualisations that listeners construct with regards to chills. This association between openness to experience and chills has since been supported through numerous investigations. In research by Nusbaum and Silvia (2011), a higher frequency of self-reported chills from participants was best predicted by the openness to experience trait, above other facets from the big five model. However, an additional question is whether this association was mediated by musical preferences, following from previous studies demonstrating a relationship between personality and preferences (Rentfrow & Gosling, 2003); interestingly, results suggest that preferences did not have a significant effect, and so the personality and chills relationship would require an alternative explanation. More recently, Colver and El-Alayli (2016) assessed openness to experience and chills in more detail, by focussing on various sub-facets of the dimension, including fantasy, aesthetics, feelings, ideas, and values. Results reinforced the relationship between chills frequency and openness to experience, and the lack of association between other personality traits. Assessing specific sub-facets, the authors concluded that only fantasy, referring to processes of meaning-making and deriving pleasure from cognitive experience, specifically correlated with a combination of self-reports and physiological indicators of chills.

It is worth noting that whilst the link between openness to experience and chills is perhaps the most consistent result across studies, occasional correlations are found between some chills experiences and other traits, such as extraversion and neuroticism (Maruskin, Thrash & Elliot, 2012), and agreeableness (Sumpf et al., 2015). Crucially, for most relationships suggested in the literature, other work reports null findings; Starcke, von Georgi, Toohonen, Laczika and Reuter (2019) found no correlation between openness to experience and chills frequency, and several studies report no relationships between chills and other big five personality traits such as agreeableness, extraversion and neuroticism (Colver & El-Alayli, 2016; Nusbaum & Silvia, 2011; Silvia & Nusbaum, 2011). Mirroring the variation found across definitions, terminology, and the psychophysiological, neurophysiological and physical indices of chills, there appear to be additional inconsistencies regarding personality traits.

Besides personality, individual differences have rarely been encapsulated in musical chills research; some researchers have suggested that females may experience musical chills more often (Benedek & Kaernbach, 2011; Panksepp, 1995), although no extensive work has been carried out with regards to explaining any possible sex differences. Grewe et al. (2007) tentatively reported that the tendency to experience chills was linked to low sensation seeking; in addition, Mori and Iwanaga (2015) report correlations between reward sensitivity and musical chills. Whilst the role of familiarity has never been explicitly investigated in chills, there have been ancillary arguments made both for a positive effect of increased familiarity on chills frequency (Grewe et al., 2009; Laeng et al., 2016), and no clear effect (Benedek & Kaernbach, 2011; Colver & El-Alayli, 2016; Nusbaum et al., 2014).

Listening Context

In any music listening experience, the other central, and less studied, aspect to consider is the listening situation or context (DeNora, 2001; North & Hargreaves, 2008). Efforts have been made to understand some qualities of prevalent listening situations that involve musical chills, both in experimental settings and everyday life scenarios. In the experimental paradigm, the frequency of chills has been assessed by comparing instances of listening alone with listening alongside friends (Sutherland et al., 2009; Egermann et al., 2011). In the context of emotional contagion processes (Juslin & Västfjäll, 2008), it was theorised that sharing an emotional response to music with others may intensify the experience, especially if listeners are comfortable around the other participants (i.e. close friends or family). However, across self-reports and skin conductance data, no significant differences were found between the two listening contexts, and this may be a result of two factors: Firstly, the effect of listening alone compared to with friends may be weak and the small sample size resulted in a statistically underpowered study; secondly, there are possible confounding variables, such as an unnatural listening situation with friends in an empirical setting. An interesting finding from this study is that there appeared to be wide individual differences in the chills experience; this is not surprising given previous considerations, but in fact the listening context seemed to have an effect, with some individual participants experiencing chills only in social situations as opposed to listening alone, and vice-versa.

Other research has approached the listening contexts of musical chills in terms of everyday life instances of the experience. In a study by Nusbaum et al. (2014), the experience sampling method was utilised, which aimed to collect data more closely representative of experiences in routine life by administering ten daily questionnaires to be completed immediately, over a week. Some descriptive results highlighted that music listening was involved in 22% of the surveys completed; of these, 14% also included a reported chills response to the music. Across a week, participants experienced on average 3.73 chills, which suggests that perhaps the prevalence of chills might not be accurately estimated in experimental conditions in comparison to everyday life activities. In terms of the listening context, engaging with music whilst alone did not significantly predict chills responses, although there was notable heterogeneity across participants. Finally, it was reported that chills were more likely with music that was chosen by the participant in question, and when the participant listened attentively to this music, potentially inferring effects of musical preference and attention. The role of choice reflects parameters comprising the appraisal approach to musical emotions, such as agency, responsibility and causation (Ellsworth & Scherer, 2003), and could be an important factor in chills experiences.

Summary

In summary, beyond the correlational approaches taken to assess the relationship between musical chills and various musical and psychoacoustic parameters, chills have also received attention from personality psychology, likely due to the inter-individual variability in the response. Additionally, important preliminary research into the effects of listening contexts has been carried out with regards to chills, addressing a problem symptomatic of music and emotion research more broadly. Of course, how the qualities of the music, listener and the situation interact to elicit a chills response is far from clear, but these interactions cannot be fully understood given that what is known about any single aspect of the listening experience in relation to chills is severely limited. Interestingly, one way of improving how we understand the links between music and a psychophysiological aesthetic phenomenon such as chills is to assess the nature of chills experienced in other aesthetic engagements, such as film, visual art or poetry; furthermore, exploring non-artistic circumstances, such as understanding the biological and evolutionary underpinnings of the physical activity characteristic of chills, could be crucial in understanding and explaining the experience within aesthetic contexts.

3.4 Chills and Other Aesthetic Engagements

In one of the first formal assessments of the chills phenomenon, Goldstein (1980) noted the reported effectiveness of music as an elicitor of the response, but alongside music were a variety of other stimuli linked to chills; these included various scenes in movies, plays, ballets or books, great beauty in nature or art, physical contact with another person, nostalgic moments and sexual activity. Indeed, to understand the relationship between music and chills, it is useful to assess the phenomenon in other aesthetic or functional contexts.

Chills, Film and Poetry

Research on aesthetic chills outside of music listening episodes has mainly focussed on responses to film scenes, directing attention to what qualities chills-eliciting film clips may possess, and whether chills indicate a specific emotional construct. Research by Benedek and Kaernbach (2011) utilised various audio excerpts from films to elicit chills in participants, finding that some film clips were particularly effective in eliciting the chills response, such as audio excerpts from the films Armageddon or Titanic. Interestingly, these scenes were not overtly joyous or positive, and in fact were suggested to convey sadness in mixed emotional contexts. Furthermore, the authors highlighted that the chills-eliciting film clips were focussed on social relationships and prosocial cues.

In further research utilising film clips, Wassiliwizky, Wagner, Jacobsen and Menninghaus (2015) presented participants with short scenes that were characterised by different combinations of foreground events and background contexts; these combinations were mainly comprised of a negative background accompanying a positive foreground event (i.e. a reunion of two people after a long, painful separation), or a positive background accompanying a negative foreground event (i.e. a character sacrificing oneself to save the people they love). These clips were anticipated to elicit states of feeling moved, a mixed emotional concept to be discussed at greater length in the theory section of this chapter. Intriguingly, a variety of film clips seemed to elicit chills in participants; these chills correlated with mixed feelings or feeling moved, but not with purely positive responses such as joy.

More recently, an experiment on chills was carried out in the context of poetry (Wassiliwizky et al., 2017b). With regards to features in poetry linked to chills, the authors reported that particularly effective lines in the poetry stimuli often highlighted communicative and social aspects, such as someone addressing a lover, or other person; other notable structural features include cadences, closure of lines, certain stanzas, and sometimes reference was made simply to the full poem in terms of chills.

Chills and Other Engagements

Besides film and poetry, chills have been assessed across different sensory modalities, and in relation to other events or engagements. In an experience sampling study, Schurtz et al. (2012) collected reports of goosebumps more broadly over a four-week period, and were interested in how involuntary and intense the goosebumps were perceived to be by participants, and what stimuli or process may have elicited the response. Through coding the written accounts provided by the participants, it was reported that the goosebumps were largely involuntary experiences, and on average were of moderate intensity. Of present interest is that whilst being cold was the most reported reason for experiencing goosebumps, elicitors could often be categorized in terms of being directly social (such as hearing an eloquent speech, or thinking about a remarkable person), or aesthetic (i.e. listening to music, viewing a piece of art). Other categories of note were feelings of fear, such as during a horror film, and romantic engagements.

Beyond the various aesthetic stimuli linked to chills in current research, one intriguing study has approached chills with regards to differing sensations, be they auditory, visual, olfactory, or gustatory (Grewe et al., 2010). Using pictures from the International Affective Picture Scale (IAPS; Lang, Bradley & Cuthbert, 1997), acoustic sounds, pieces of music, tactile stimulation (feather or head massager) and gustatory stimuli (grapefruit or lemon juice), the frequency of chills were assessed across participants, whilst skin conductance, heart rate and breathing rate data were collected. Interestingly, many different types of stimuli were reasonably effective in eliciting chills across different participants, and chills were experienced alongside stimuli judged to vary in terms of valence (i.e. positive or negative affect). Tactile stimulation elicited the highest frequency of chills, and whilst most music excerpts elicited positive emotions alongside chills, the same could not be said of certain sounds and images, which may have resulted in negative chills experiences. A rather unique finding is that numerous participants were reportedly able to elicit chills simply through internal mental stimulation, such as remembering emotional events or memories from one's past. This result touches closely on recent, novel evidence of a small sample of the population who appear to have voluntary control of their piloerection response (Heather, Fayn, Silvia, Tiliopoulos & Goodwin, 2018).

Summary

When taking into consideration the phenomenon of chills, its apparent occurrence with a variety of different stimuli in numerous sensory modalities, and the various correlations established in research between the response and structural aspects of music, expressive elements of film, and linguistic content of poetry, formulating an intuitive explanation of the processes underlying chills provides a substantial challenge. Furthermore, any explanation, theory or framework of musical chills should not only encapsulate the relationships observed between the response and musical features, individual differences and listening contexts, but also relate to, and be informed by, neurophysiological evidence of possible brain processes involved in the experience, the subjective feeling components of what is a peak emotional response, and the incidence of the phenomenon outside of music. What follows is a critical assessment and formalisation of existing theories proposed to explain musical chills, and aesthetic chills more broadly.

3.5 Theories of Musical Chills

When considering the current state of research with regards to musical chills, it appears clear that chills are a highly pleasurable experience, and they are potentially elicited by certain musical or psychoacoustic features, such as dynamic changes, loudness and roughness, or unexpected harmonic progressions. On the other hand, chills appear to be quite rare in everyday life (Nusbaum et al., 2014), largely dependent on idiosyncrasies of the listener (Grewe et al, 2009; Nusbaum & Silvia, 2011), and likely mediated by the listening context and situation, not unlike any emotional experience with music. However, chills are particularly notable as they involve, as per current conceptualisations, thermoregulatory responses such as gooseflesh and shivers, and physiological behaviour indicative of the fight-or-flight response such as skin conductance, heart rate and pupil dilation (Craig, 2005; Grewe et al., 2007; Laeng et al., 2016). How music appears to be successful in eliciting adaptive physical responses in pleasurable circumstances is a challenge to explain, and comprehensive theoretical accounts of the chills phenomenon are rare. However, this challenge should be attempted, to clarify and understand musical chills; this affords numerous implications for broader research, such as understanding and evaluating proposed underlying psychological mechanisms of musically induced emotions, and emotion theories including basic emotions, appraisals and constructionist approaches.

Developing from the extant research on chills with music and other aesthetic engagements, and existing hypotheses regarding theories of the chills phenomenon, this section will introduce, extend and formalise theories of musical chills for the first time, resulting in two main theoretical accounts of the chills experience; these are derived from the two primary evolutionary functions of goosebumps, namely threat-signalling and thermoregulatory functions (**Figure 3.1**). The focus on goosebumps is motivated by the fact that it remains the only physical response to be objectively measured in chills research, in contrast to shivers and tingling sensations. These two theories are henceforth labelled *vigilance theory* and *social bonding theory.*

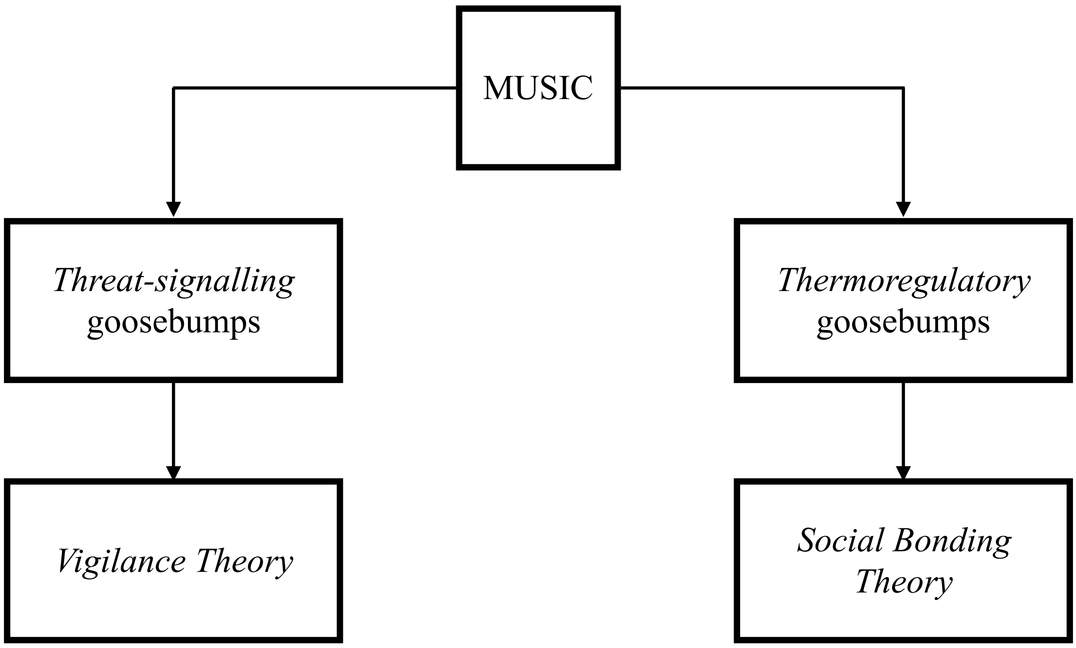

Figure 3.1: Visualisation of the evolutionary antecedents of vigilance theory and social bonding theory, derived from the two primary functions of goosebumps (threat-signalling, and thermoregulation).

3.5.1 Vigilance Theory

The first theory underlying musical chills is derived from processes of attention, vigilance, and possibly fear. This *vigilance theory*, posited briefly by Huron (2006), is derived from the threat-signalling functionality of goosebumps, in which the goosebumps reaction occurs in response to a perceived or incoming threat (Darwin, 1872), serving three purposes: Firstly, goosebumps allow the host to appear larger and more intimidating; secondly, this visual enlargement serves as a signal for conspecifics, communicating a possible, imminent threat; and thirdly, the contraction of muscles at the base of the hairs would limit blood loss in the event of injury following engagements with a threat (IJzerman et al., 2015).

Musical Expectations and Auditory Looming

There are several routes in which music may be able to elicit goosebumps through threat-signalling functions, many of which converge on the ideas of anticipation and expectation. As highlighted in **Chapter 2**, expectancy violations in music appear to be perceptually salient (Besson & Faïta, 1995; Koelsch et al., 2008; Poulin-Charronat, Bigand & Koelsch, 2006), and are linked to emotional arousal (Egermann et al., 2013; Meyer, 1956; Steinbeis et al., 2006). Theoretically, the violation of musical expectations is capable of eliciting goosebumps. Huron and Margulis (2010) note that incorrect predictions are maladaptive, and likely result in increased vigilance or attention; additionally, fear may serve as a behavioural motivator for improving and refining the predictive process, to aid survival. In the ITPRA model of musical expectancy, Huron (2006) posited that expectancy violations could engage the fight-or-flight system, elicit sympathetic nervous system arousal, and result in experiences of chills. In this context, it is difficult to explain why the chills response would reflect moments of peak pleasure (Blood & Zatorre, 2001); however, Huron (2006) specifies a process called *contrastive valence*, in which the initial, negative appraisal of expectancy violations is followed by a conscious, aesthetic appraisal (Juslin, 2013), where the context is 'safe', and potentially positive. In this safe aesthetic context, the threat-signalling physical reactions may then be perceived and interpreted differently by the listener (James, 1894; Russell, 2003). This contrast may serve to enhance the pleasurable aspects of the experience, partially analogous to the excitation-transfer effect (Cantor & Zillman, 1973), although little research has addressed this empirically.

Besides expectations derived from musical syntax developments, the threat-signalling goosebumps reaction may be elicited by lower-level features in music, such as sudden dynamic changes or crescendos, and psychoacoustic features. These aspects of music may imply a role of brain stem reflex mechanisms (Juslin & Västfjäll, 2008) as opposed to musical expectancy, but theoretically sudden changes in external events appear linked to vigilance, and possibly fear; consider for example the startle reflex literature (Lang, Bradley & Cuthbert, 1990; Miller et al., 2002). In contrast, crescendos, reflecting a more gradual increase in dynamics, may be intuitively mapped on to a perceptual process labelled auditory looming; this process refers to the perception of a sound source as approaching, often achieved through the gradual increase of acoustic intensity or loudness (Ghazanfar, Neuhoff & Logothetis, 2002). Auditory looming has been theorised to hold perceptual salience and adaptive significance, in that an approaching sound source may constitute a threat or need for action readiness (Neuhoff, 2001). The perceptual salience of sounds increasing in acoustic intensity has been confirmed through a variety of measures; for example, sounds with increasing intensity ramps are perceived to change more in terms of loudness compared to decreasing intensity sounds (Bach, Neuhoff, Perrig & Seifritz, 2009; Neuhoff, 2001), and are judged to be longer in duration (Grassi & Darwin, 2006; Ries, Schluach & DiGiovanni, 2008). Participants also underestimate the 'time-to-arrival' of a sound source with increasing intensity ramps (Neuhoff, Planisek & Seifritz, 2009), and reaction times to photographs were quicker following sounds with increasing intensity compared to decreasing (Tajadura-Jiménez, Väljamäe, Asutay & Västfjäll, 2010). Furthermore, increasing sound intensity has been linked to increases in skin conductance, alongside heart deceleration (Bach et al., 2008); in the same study, significant increases in amygdala activity were reported for the increasing intensity sounds, further suggesting a perceptual salience of auditory stimuli with a quality comparable to the crescendos in music that have been associated with chills in existing research.

Explanatory Power

The vigilance theory of musical chills can explain a sizeable portion of existing research that describes relationships between musical structure and chills. For example, the elicitation of a quick, attentive and vigilant response that recruits a goosebumps reaction may be achieved by the sudden dynamic changes or unprepared harmonies linked to chills (Grewe et al., 2007; Guhn et al., 2007; Sloboda, 1991); similarly, the crescendo associated with chills by Panksepp (1995) may tap into fear and vigilance mechanisms through auditory looming processes (Ghazanfar et al., 2002). By extension, there is also a possibility that fear and vigilance processes underlie musical chills that have been correlated with auditory roughness (Grewe et al., 2007; Nagel et al., 2008), an auditory property recently linked to the human scream, amygdala activation and danger processing (Arnal, Flinker, Kleinschmidt, Giraud & Poeppel, 2015).

Awe

In the context of vigilance mechanisms underlying musical chills, an emotional state that has repeatedly been implicated is awe. Awe is an enigmatic emotional state that is difficult to characterise, and has been situated in numerous contexts, including religion (Keltner & Haidt, 2003), sociology (Durkheim, 1887/1972), philosophy (Burke, 1757/1990), and psychology (Razavi, Zhang, Hekiert, Yoo & Howell, 2016; Shiota, Keltner & Mossman, 2007; Stellar et al., 2018). Additionally, awe has been associated with the experience of chills and goosebumps (Konečni, 2005; Schurtz et al., 2012).

Emotion theorists have occasionally offered holistic definitions of awe; Lazarus (1991) described awe as an ambiguous negative state with differences in valence depending on contexts and appraisals; Ekman (1992) highlighted awe as a possible distinct emotion, but offered little regarding its expression or elicitors; Izard (1977) described awe as an intense variation of interest; finally, Frijda (1986), using the closely related descriptor of wonder, linked the experience to surprise and being in the presence of something unexpected. In one of the first thorough formulations of the awe concept however, Keltner and Haidt (2003) claimed that there were two principal features of awe, labelled *vastness* and the *need for accommodation*. Vastness describes anything that is experienced by someone as being larger than themselves; although this can be associated with physical size, vastness is not restricted in this way, and can refer to social size (i.e. superior skill, authority, prestige), and might be abstracted even further, to an elegantly simple mathematical proof for example. The need for accommodation as a second central feature of awe is derived from the idea that mental structures and representations may need to be adjusted and reformatted when a person struggles to assimilate new experiences into existing schemata (Piaget & Inhelder, 1969). In other words, awe may be elicited when existing mental structures are challenged, such as when we fail to make sense of something of great vastness. Additionally, accommodation of the new experience or encounter may or may not be achieved, potentially resulting in differential experiences of awe, ranging from frightening to enlightening (Keltner & Haidt, 2003). Indeed, the authors consider the notable variations that are likely across experiences of awe, and suggest that there are an additional five 'flavouring' features that may augment the response in some way; these include threat or danger (imbuing awe with fear), beauty, ability, virtue, and supernatural causality.

Elsewhere, Konečni (2005) described an 'aesthetic trinity' of thrills, being moved and awe, suggesting that these phenomena are variations of the same experience, and are differentiated by increasing intensity in this order. In describing experiences of the sublime, numerous aspects are considered important for strong emotions such as awe, including physical grandeur, reflecting vastness (Keltner & Haidt, 2003), rarity and beauty, and existential security or lack of real danger, which differentiates the response from fear, whilst sharing its dimension. It is important to note at this point that Konečni (2005) suggests that awe and the state of being moved (Menninghaus et al., 2015) are comparable, a matter for discussion towards the end of the current chapter.

Following these initial accounts of awe, a series of studies were carried out by Shiota et al. (2007), in which they explored the information-focus of awe experiences, effects of the response on self-concepts, and self-diminishing effects of awe. In the first study, participants were asked to recall and describe a recent event that elicited either awe or happiness, with results highlighting several elicitors linked to either state; experiences of nature, art, music, and another's accomplishments were significantly linked to awe, whereas happiness was most clearly associated with social interactions and the expressive behaviour of smiling, suggesting that whilst awe may be positive, it can be distinguished from joy or happiness (see also Darbor, Lench, Davis & Hicks, 2016). Next, concepts of vastness and the diminished self were explored, with participants again recalling events related to either nature or accomplishment (feelings of pride). Notably, when asking for ratings linked to emotion, vastness and self-diminishment, the events linked to nature were associated with higher ratings of awe and rapture compared to accomplishment events; furthermore, feelings of the small self and perceptions of vastness were more intense for nature events compared to those linked to accomplishments. The third study from Shiota et al. (2007) found that by measuring dispositional awe, joy and pride via the Dispositional Positive Emotions Scales (Shiota, Keltner & John, 2006), awe was negatively correlated with a need for cognitive closure, suggesting that certain individuals may derive pleasure from cognitively challenging events that produce a need for accommodation. Overall, these findings offer support for vastness and need for accommodation as two key components of awe experiences, and holistically characterise awe as a response elicited by novel and complex stimuli (Campos, Shiota, Keltner, Gonzaga & Goetz, 2013). The existing correlational literature on musical chills, and the proposed vigilance theory, might best align with experiences of awe, given that vast, complex events in music may reflex expectancy, reflex and auditory looming processes. However, it is important to note that studies have rarely considered musical awe; one recent exception is work by Silvia, Fayn, Nusbaum and Beaty (2015), in which awe with music was associated with openness to experience.

More recently, research has become more prevalent with regards to awe; for example, two studies (Campos et al., 2013; Piff, Dietze, Feinberg, Stancato & Keltner, 2015) linked awe to experiences of the small-self, in which one feels small relative to their environment or surroundings. A study of threat-based variants of awe, in comparison to positive variants, showed a link to lower self-control and certainty in the experience, and more pronounced feelings of fear (Gordon et al., 2016); recently, horror was explored alongside awe as responses linked to schema incongruence (Taylor & Uchida, 2019), suggesting that the type of incongruence was an important factor in distinguishing between responses. Awe has also been linked to spiritual experiences (Preston & Shin, 2017), and feelings of humility (Stellar et al., 2018). Finally, a novel route of research has started to utilise virtual reality applications and technology to capture experiences of awe in experimental settings (Chirico, Yaden, Riva & Gaggioli, 2016), in contrast to the common method of collecting retrospective accounts of the response; Chirico et al. (2017) used immersive 3D video stimuli to elicit higher ratings of awe compared to 2D video stimuli; following this, Chirico, Ferrise, Cordella and Gaggioli (2018) used different virtual reality environments (mountaintop, space, forest) to elicit experiences of awe; finally, Nelson-Coffey et al. (2019) used virtual reality to simulate a spacewalk (viewing Earth from space) to elicit experiences of awe.

Summary

The vigilance theory of musical chills suggests that through processes of musical expectation, brain stem reflexes and auditory looming, the goosebumps response may be elicited; this may be explained by the threat signalling functionality of goosebumps (Darwin, 1872; IJzerman et al., 2015). Possible elicitors of this musical chills response may include crescendos (Guhn et al., 2007; Panksepp, 1995), sudden dynamic changes (Guhn et al., 2007 Sloboda, 1991), new or unprepared harmonies (Sloboda, 1991), and increases in loudness or auditory roughness (Grewe et al., 2007; Nagel et al., 2008). This theory of musical chills is somewhat consistent with the enigmatic emotional state of awe, such that experiencing awe is reliant on encountering a stimulus perceived to be vast and challenging to one's perceptual and cognitive framing (Keltner and Haidt, 2003; Shiota et al., 2007), and is associated in some ways to fear processing (Gordon et al.,2016; Konečni, 2005; Taylor & Uchida, 2019).

However, there are certain issues and conclusions from existing research on musical chills that unsettle the foundations of the vigilance theory. Firstly, researchers have often concluded that musical chills are highly idiosyncratic, and are associated with personality traits (Colver & El-Alayli, 2016; Nusbaum & Silvia, 2011; Starcke et al., 2019; Sumpf et al., 2015), familiarity (Benedek & Kaernbach, 2011; Grewe et al., 2009; Rickard, 2004; Salimpoor et al., 2009), and most likely the prevailing mood state of the individual, a factor rarely considered in the literature. Consequently, chills are mostly observed to be inconsistent both inter- and intra-individually. These conclusions contradict the idea that vigilance mechanisms possibly linked to fear, a central emotion crucial for survival, are the prominent underlying processes of musical chills; for example, should fear or vigilance result in musical chills, we would expect, for neuro-typically developing individuals, comparable and reasonably predictable response patterns, given the importance of these adaptive mechanisms across all individuals. In fact, the opposite appears to be true, with only rare moments of convergence found in previous studies. However, there is still the possibility of individual traits mediating the efficacy of music to elicit vigilance processes and chills through low-level and high-level features, such as trait anxiety levels. Furthermore, there may be an arousal threshold that needs to be passed for chills to be elicited, and this could vary across individuals; this may explain why not all expectancy violations or dynamic changes are sufficient for eliciting the threat-signalling goosebumps response across listeners.

Secondly, the fear response does not appear to be an immediately intuitive explanation for chills responses reported with film clips and poetry (Wassiliwizky et al., 2015; Wassiliwizky et al., 2017b). Benedek and Kaernbach (2011) noted that the most effective audio clips were from films with clear social aspects and mixed emotional qualities, and whilst vigilance processes cannot be discounted in these experiences, it is unclear as to how chills in engagements with film and poetry reflect the proposed vigilance mechanisms underlying chills whilst listening to music. Furthermore, Grewe et al. (2010) found that physical contact through way of a scalp massager, was particularly effective at eliciting some type of chills response in participants (see also Goldstein, 1980); it is unclear whether vigilance processes are implicated in these scenarios. Goosebumps have also been reported in response to various videos depicting bittersweet scenarios, such as a baby elephant being rescued, acts of altruism, and emotional reunions (Schubert, Zickfeld, Seibt & Fiske, 2017). Finally, chills linked to musical features such as the entrance of solo instruments

(Grewe et al., 2007), and alternations between solo and accompaniment parts (Guhn et al.,2007) are not easily accommodated by the vigilance theory.

Importantly, although musical chills serve as the primary focus, any theory of the chills phenomenon should encapsulate the phenomenon across additional aesthetic engagements. The current vigilance theory of chills explains numerous correlations in the extant literature, but does not fully encompass the variability of the response and relationships with music and other aesthetic objects. Consequently, alternative explanations may be required, leading on to the second main theoretical formulation of the musical chills phenomenon.

3.5.2 Social Bonding Theory

The second theory posited regarding the underlying psychological mechanisms of musical chills is that of *social bonding theory*. Like vigilance theory, the link between social bonding and chills is primarily derived from the evolutionary functions of goosebumps; however, in contrast to vigilance theory the thermoregulatory functionality of goosebumps serves as the foundational aspect, as opposed to threat-signalling.

Thermoregulation and Social Relationships

It has been theorised that social bonding and distress circuits within the mammalian brain developed from ancient, pre-existing neural systems that may have processed low-level experiences such as pleasure or pain, place attachment, and thermoregulation (Nelson & Panksepp, 1998; Panksepp, Knuson & Pruit, 1998). Indeed, it has been suggested that the socio-emotional systems and thermoregulatory neural circuits are closely situated and related in the brain (Panksepp, 1998; Panksepp & Bernatzky, 2002). The relationship between social bonding and thermoregulation may be explained by a recent social thermoregulation hypothesis (IJzerman et al., 2015); the main principle is that social closeness and thermoregulatory processes were gradually coupled and intertwined in humans over the course of evolution. As human primates are historically quite poor at self-thermoregulation, especially without the pervasive modern amenities such as clothing, it is theorised that humans utilised growing group sizes to share body heat with one another; this would allow for more efficient control over internal body temperatures, to the mutual benefit of all others involved, whilst developing social bonds through repeated proximity and physical closeness. Resulting from this persistent, adaptive behaviour, it is possible that social systems in the brain are adjacent and overlapping with thermoregulatory systems.

The link between temperature and social concepts is common in colloquial English language; we might give someone the ‘cold shoulder’, or judge another as having a warm or cold personality. These associations between temperature, thermoregulation and social processes are not superficial however, and recent research has offered some new insights into these relationships. For example, Inagaki and Eisenberger (2013) asked participants to read ‘socially warm’ messages from family and friends, and to also hold a warm or neutral object. Results showed that there were phenomenological similarities across social and physical warmth conditions, and an fMRI scan further suggested that feelings of social and physical warmth shared neural activity in the ventral striatum and middle insula; importantly, it was claimed that pleasure was not mediating brain activity in these relevant areas, with social and physical warmth activity being distinguished from activity in a purely pleasurable condition. In another study by Kang, Williams, Clark, Gray and Bargh

(2011), participants firstly either held a cold or warm object, and then proceeded to play through an economic trust scenario; the results suggested that temperature priming had a significant effect on the investment made by participants into an anonymous partner in the economic game, with the warm prime leading to more investment, interpreted as heightened levels of interpersonal trust. In a slightly different paradigm, the links between social and thermoregulatory processes have been assessed with regards to perceiving room temperature; performing environmentally friendly deeds may result in an estimating bias for higher ambient temperatures (Taufik, Bolderdijk & Steg, 2015), and the recall of events involving social exclusion resulted in an estimate bias for lower room temperatures (Zhong & Leonardelli, 2008). In a ball toss paradigm, IJzerman et al. (2012) simulated feelings of social exclusion in some participants, and found evidence for lower levels of body temperature, compared to those who were socially included during the ball toss game. Finally, Inagaki, Irwin, Moieni, Jevtic and Eisenberger (2016) found an association between higher oral temperatures and feelings of social connectedness; this has more recently been extended by Inagaki and Human (2019), finding a covariance of moment-to-moment changes in internal body temperature and social connection over a week.

Communal Sharing Relations

In contrast to the mechanisms of musical expectancy, brain stem reflexes and auditory looming underlying the vigilance theory of musical chills, the social bonding theory is linked to various possible processes related to empathy, social cognition and memory. Currently, the closest formulation to a mechanism underlying chills and social bonding is the intensification of communal sharing relations (Fiske, Seibt & Schubert, 2017); this process has been linked to various emotional states that, as will be highlighted, are all associated with chills experiences.

Communal sharing relations (CSRs) form a component of a larger, social relational theory, in which four models were developed to explain social relations (Fiske, 1992). The CSRs, at a basic level, characterise social relations in which materials and objects are had in common with another; this act and acceptance of sharing may indicate close kinship or strong social bonds, and has been labelled 'prescriptive altruism' (Fortes, 1983), 'householding' (Polanyi, 1966), and 'generalised reciprocity' (Marshall, 1977). However, CSRs extend beyond sharing of materials, to aspects including mutual aid, sharing of land and terrain, and specific symbols of identity and connection, such as family heirlooms. More generally, CSRs constitute, through various ways, a sense of equivalence and sameness between oneself and another person, object, identity, culture, idea, or something as grand as the Universe itself (Fiske et al., 2017).

Notably, there are at least two different induction routes for intensified CSRs, namely *shared experience* and *empathic concern*. Firstly, shared experience refers to an establishing of equivalence across bodily substances, surfaces or motions; this has elsewhere been labelled 'consubstantial assimilation' (Fiske, 2004), and may refer to ritualistic approaches, in the case of offering one's blood during a ritual, but may also be a more mundane instance in numerous contexts. One example of this may be a football match; in such an environment, any one attendee would likely be surrounded by a great number of people, dressed in similar team colours, singing their team chants and songs in unison, and taking part in synchronised celebrations at certain points. This environment offers a strong opportunity for shared experience, and the sudden intensification of CSRs. A more relevant environment that resembles the football scenario is the live music concert, gig or rave (Takahashi & Olaveson, 2003), in which, depending on the style of music, audience members are encouraged to dance along with the music or with each other, and to sing along together with the performers. Given the documented, close associations between music listening and social identity, particularly in adolescence (Laiho, 2004; North, Hargreaves & O'Neill, 2000), connecting both with your performers or idols, and others who may dress similarly and share the enthusiasm and love for the music, may present an excellent opportunity for intensified CSRs; this is reflected in part by a study into strong emotional experiences with live music (Lamont, 2011), in which some participants describe a similar experience of being connected with other attendees around them.

Secondly, empathic processes may result in intensified CSRs. A pertinent aspect of empathy is empathic concern, which has been linked with experiences of chills, tears and feelings of warmth in one's body (Zickfeld et al., 2017); in this study, the researchers proposed that empathic concern, a culturally appropriate, incongruent response (i.e. not mirroring the observed emotion), may result in intensified CSRs. In these instances, a typical eliciting stimulus may express unfortunate circumstances, or portray a person or other in need of help or support (Batson, 1990; Davis, 1980). Consequently, it may be possible that certain empathic processes can elicit a sudden, intensified relation between one person and another entity, as feeling the need to console another may re-affirm the social bonds already present.

Being Moved and Related States

The proposed underlying mechanism of intensified CSRs in the social bonding theory of chills may be utilised to accommodate numerous, related emotional states, such as being moved, elevation, admiration, nostalgia and poignancy. Notably, several of these states have been linked to the experience of goosebumps and chills, a central pattern of results that further connects social bonding to chills experiences.

The main emotional state attributed to CSRs and chills is being moved. Although this enigmatic response has been alluded to in earlier literature (Frijda, 1988), it is not until recently that the experience, described linguistically with phrases such as feeling stirred, touched and moved (Kuehnast, Wagner, Wassiliwizky, Jacobsen & Menninghaus, 2014), has received sustained empirical attention. In the current research, being moved may be described as a pleasurable emotional experience, characterised largely by a mixture of joy and sadness (Menninghaus et al., 2015). In an earlier study that focused on the Japanese approximation of being moved labelled *Kandoh*, Tokaji (1999) reported that experiences of Kandoh could often be accompanied by feelings of joy (73.2%) and by sadness (40.6%); in a further study, Tokaji (2003) showed that Kandoh reported by participants could not only be accompanied by joy or sadness, but also that this could be manipulated through a single film clip which was contextualised either positively (relationship anniversary) or negatively (ode to passed lover). There is increasing attention and discussion regarding being moved, and its position as a distinct emotional response; Cova and Deonna (2014) suggest that being moved is an intentional, object-directed state with no overt action tendencies, in which positive human values are brought to the foreground and become salient in experience. In an exploration of the conceptual structure of being moved, Kuehnast et al. (2014) noted that the experience may be linked to three categories of elicitors: Firstly, personal life events such as weddings, funerals and births; secondly, aesthetic engagements, primarily with films and music; and finally, natural calamities in the world such as earthquakes, understood in contexts of being moved by perceiving human suffering as opposed to the event itself. In a recent conceptualisation of being moved, Menninghaus et al. (2015) reiterated various elicitors, including social relationships, critical life events, political events, and both nature-related or art-related events; furthermore, Cova and Deonna (2014) suggest several elicitors, such as a reconciliation between two estranged friends, last words from a dying mother to child, or unexpected kind gestures. In addition to these prosocial aspects, Seibt et al. (2017) suggested that interpersonal closeness predicted feelings of being moved.

Although there is no consensus that being moved describes a distinct, adaptive emotion (Cova, Deonna & Sander, 2017), further research has investigated some of the variability within the concept. For example, utilising various film clips, Wassiliwizky et al. (2015) suggested that being moved can be divided into two constructs, mainly being *joyfully* moved, or *sadly* moved. These experiences also map onto various combinations of positive and negative themes in film clips; for example, joyfully moving scenarios may involve a positive foreground event (e.g. a reunion) emerging from a negative background context (e.g. a long separation). Alternatively, sadly moving scenarios may be comprised of a negative foreground event (e.g. self-sacrifice) emerging from a positive background, or as having some positive consequences (e.g. to save family and loved ones).

There are several emotion concepts that seem related to being moved, including elevation, admiration, nostalgia and poignancy. Elevation has been linked to acts of moral beauty and virtue that have no direct bearing on the self (Haidt, 2003); these may include observed generosity, charity, or fidelity. This proposed emotion has a strong social basis, and has been suggested to affect behaviours, such as increasing the desire to perform altruistic deeds (Algoe & Haidt, 2009). In contrast, admiration is characterised as a response to non-moral excellence (Algoe & Haidt, 2009), typically involving the witnessing of extraordinary talent, success, achievement or skill; admiration has further been categorized as an 'appreciating' emotion (Ortony, Clore & Collins, 1988). The concept of nostalgia, a seemingly self-relevant emotion associated with recalling personal experiences from one's past (Wildschut, Sedikides, Arndt & Routledge, 2006), bears interesting similarities to being moved, regarding experience and elicitors. Nostalgia has been discussed in terms of positive affect (Davis, 1979), negative affect (Ortony et al., 1988), and a mixture of the two (Johnson-Laird & Oatley, 1989); also, in a series of studies (Wildschut et al., 2006; Wildschut, Sedikides, Routledge, Arndt & Cordaro, 2010), nostalgia appeared to be a positive experience in response to loneliness, suggesting that nostalgia may serve to strengthen social bonds, heighten social connectedness, and increase positive affect. Finally, the concept of poignancy is partially comparable to being moved, and is specifically associated with the anticipation of an ending of some sort (Ersner-Hershfield, Mikels, Sullivan & Carstensen, 2008), or not having something or someone after having had previously (Duncker, 1941). Research on poignancy suggests that older adults report this experience more frequently than younger adults (Carstensen, Pasupathi, Mayr & Nesselroade, 2000; Ong & Bergeman, 2004), and is accompanied by both happy and sad feelings (Ersner-Hershfield et al., 2008).

Recent work has broadened the conceptual scope to encapsulate being moved and related states, with Fiske et al. (2017) proposing an emotional concept labelled *kama muta* (Sanskrit for ‘moved by love’). This concept, linked to intensified CSRs, has received cross-cultural support in response to moments of love, affection and identification (Seibt et al., 2018); further work found kama muta experiences in response to political campaign advertisements in the weeks leading up to the recent US general election (Seibt, Schubert, Zickfeld & Fiske, 2019). Finally, kama muta and being moved was linked to bittersweet videos with prosocial cues (Schubert, Zickfeld, Seibt & Fiske, 2018). It is possible that being moved, elevation, admiration, nostalgia and poignancy reflect different variants of the kama muta construct. These differences may depend on the induction route of CSRs (e.g. shared experience or empathic concern), and the level in which CSRs are intensified; for example, being moved may be elicited by first-person CSRs, involving internal processes such as memory, second-person CSRs between oneself and another, and third-person CSRs, in which social bonds and connections are observed between others.

Explanatory Power

The states of being moved, kama muta and related concepts, all purported here to be derived from intensified CSRs, are the core experiential aspects of the social bonding theory of chills; additionally, this social bonding account carries substantial explanatory power with regards to numerous associations between chills, being moved and prosocial elicitors.

The emotional states of being moved, kama muta, elevation and admiration have all been linked to experiences of chills. Benedek and Kaernbach (2011) suggested that experiencing goosebumps with film audio clips was indicative of being moved; moreover, Wassiliwizky et al. (2015) highlighted associations between ratings of being moved and chills experiences with bittersweet film scenes. Real-time ratings of being moved also correlated with the incidence of goosebumps and ratings of social closeness (Schubert et al., 2018). The recent conceptualisation of being moved (Menninghaus et al., 2015) included chills as a primary physical indicator of the experience; this is echoed by Fiske et al. (2017) and their formulation of kama muta. The link between chills and prosocial cues and characteristics in poetry is also best understood from the social bonding perspective (Wassiliwizky et al., 2017b); moreover, some goosebumps responses during religious contexts are described by Inbody (2015), and these may be understood in terms of communion, shared experience, and the intensification of CSRs. Regarding related states, experiences of moral elevation, or witnessing good deeds, has been linked to physical sensations including warm feelings in the chest, goosebumps and tingling sensations (Haidt, 2003; Silvers & Haidt, 2008); similarly, feelings of elevation and admiration were associated with goosebumps and chills (Algoe & Haidt, 2009).

As highlighted, the extant correlational literature on chills in the music listening context mainly describes features such as crescendos, dynamic changes and unexpected harmonies (Grewe et al.,2007; Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991). In contrast, little research has directly assessed musical chills in relation to social bonding processes; this is a difficult route of investigation, particularly when music, with its floating intentionality (Cross, 2014), does not consistently express or convey explicit narratives or social cues. Despite this, there is some adjacent evidence to suggest that social bonding theory can explain numerous instances of musical chills. Panksepp (1995) suggested that certain acoustic qualities in music may elicit chills through their resemblance to mammalian distress vocalisations emitted during moments of social separation. These signals are salient and prominent in parent-offspring interactions (Pettijohn, 1979), which when heard result in motivational and behavioural responses designed to seek and achieve social reunion; the chills response may serve as a behavioural motivator to achieve social closeness and warmth. However, there is little understanding of what features could elicit a social separation or bonding response; an obvious candidate would be the human voice in music, a sound that holds a privileged position of communicative salience for human listeners (Belin, Zatorre, Lafaille, Ahad & Pike, 2000). Indeed, the parameters utilised by music to express and elicit emotion have plentiful comparisons with those employed through speech prosody (Ilie & Thompson, 2006; Juslin & Laukka, 2003); therefore, 'super-expressive' instruments that may resemble the human voice such as the violin or cello (Juslin, 2001), may be better suited to elicit empathic responses and intensified CSRs at some level. Additional reasons to suspect that certain psychoacoustic parameters may be linked to social bonding processes and chills are found when assessing the related state of ASMR. This experience often has a strong auditory basis, and may be elicited by quiet voices and whispering (Barrett & Davis, 2015), alongside a close visual proximity of the actor to the video recorder (Kovacevich & Huron, 2019), and personal attention from actor to viewer (Barrett & Davis, 2015). These cues may infer social proximity, intimacy, and a scenario for developing CSRs between the audience and actor, although alternative explanations have been proposed (Kovacevich & Huron, 2019).

A more immediate feature that might be linked to social bonding processes during music listening is that of lyrics, a pervasive characteristic of contemporary popular music. Notably, the role of lyrics in music and emotion has rarely been studied

(Ali & Peynircioglu, 2006; Brattico et al., 2011; Fiveash & Luck, 2016; Mori & Iwanaga, 2014b), and has never been assessed in relation to chills; however, in the social bonding context, lyrics may offer the most immediate opportunity for listeners to relate to personas or characters within a narrative, to feel empathic towards them, share experiences, or to perceive social interactions within the music. Instrumental music may achieve similar results, as Robinson and Hatten (2012) note that music can be listened to in terms of personas, characters and interactions. More recently, empirical work, using improvised performance dyads (Aucouturier & Canonne, 2017), found that when a performer had to communicate one of five social relationships to another performer, these relationships were often decoded correctly based on instrumental performance and improvised interactions; participants external to the performances were also successful in decoding interpersonal relationship qualities when listening to the recordings.

Further adjacent evidence for links between social bonding and musical chills is provided by studies on being moved and pleasurable sad music. Vuoskoski and Eerola (2017) proposed that the pleasure some listeners describe when engaging with sad music was mediated by ratings of feeling moved; in addition, a positive relationship between being moved by music and trait empathy was documented by Eerola et al. (2016), suggesting, alongside the various elicitors documented for being moved, that the response is closely associated with empathic and social experience. It is worth noting that Panksepp (1995) found sad music to be generally more effective at eliciting chills in participants, and further proposed that a bittersweet mood or atmosphere expressed through music could be a powerful elicitor. This bittersweet mood or atmosphere fits neatly with the combination of positive and negative qualities in film clips that are linked to states of being moved and chills (Wassiliwizky et al., 2015).

An additional point linking musical chills to social processes is the suggested relationship between musical chills and altruism (Fukui & Toyoshima, 2014), although comparatively null results were reported by Konečni, Wanic and Brown (2007). Finally, participants sometimes describe their chills experiences with pseudo-social analogies; for example, some listeners reported feelings of being 'one' with the music during chills experiences (Laeng et al., 2016), alike to a parasocial interaction between listener and music (see Schäfer & Eerola, 2018).

Summary

In contrast to the vigilance theory of musical chills, utilising evolutionary functions of threat signalling for goosebumps, the social bonding theory is instead derived from thermoregulatory functions of goosebumps, currently explained by a possible crossover and interplay between thermoregulatory and social processing systems in the brain (Inagaki & Eisenberger, 2013; Nelson & Panksepp, 1998; Panksepp, 1998; Panksepp & Bernatzky, 2002 Panksepp et al., 1998); this crossover may have developed through evolution, due to the process of sharing body heat with other conspecifics in close proximity, to address inefficiencies of thermoregulation in isolation (IJzerman et al., 2015). Substantial support for this theory is found in the broader aesthetic literature, considering chills in response to films and poetry, and the associations between chills and emotions with pronounced social underpinnings, such as being moved, kama muta, elevation and admiration.

Like the vigilance theory however, there are current limitations to the social bonding theory of chills, mainly attributed to a lack of research in music and emotion. As most of the evidence for social chills is derived from engagement with film, literature and other media (Benedek & Kaernbach, 2011; Schubert et al., 2018; Wassiliwizky et al., 2015; Wassiliwizky et al., 2017b), it is yet unclear as to how music, particularly instrumental music, may elicit the phenomenon.

Furthermore, there are current complications in understanding the exact reasons behind the goosebumps or chills response in the social bonding context. Panksepp (1995) suggested that distress vocalisations simulated in music may induce phenomenological feelings of coldness that motivate social reunion; this coldness would engage the cold-defence mechanism of goosebumps. However, in the case of being moved or kama muta, there is no clear experience of coldness that would trigger a cold-defence response; in fact, the opposite is proposed in the phenomenology of kama muta (Fiske et al., 2017), such that warmth and warm feelings in the chest are highlighted as common psychophysiological indicators of the experience. One possible explanation may be to view the elicitation of goosebumps as an artefact, in instances where the social bonding or empathic experience is of enough intensity to result in a crossover and spreading of brain activity from social to thermoregulatory processes; in this account, there may not be an explicit need for coldness that requires a defensive response. Despite this, further research is required on numerous fronts to elucidate the social bonding perspective and being moved states, and how the experience of chills may be explained in these contexts.

3.6 Distinct Chills Experiences

The current review of chills demonstrates a crucial, pervasive theme of *variation* across the research, data and theories. A wide variety of stimuli are linked to chills, such as music, film, videos, poetry, physical contact and gustatory stimulation (Goldstein, 1980; Grewe et al., 2007; Grewe et al., 2010; Guhn et al., 2007; Panksepp, 1995; Schubert et al., 2018; Sloboda, 1991; Wassiliwizky et al., 2015; Wassiliwizky et al., 2017b). Within each type of stimulus, there are further variations and correlations reported between chills and features or characteristics of the aesthetic item, such as structural aspects of music (Panksepp, 1995; Sloboda, 1991), mixed affective scenarios in film (Wassiliwizky et al., 2015), and social cues in poetry (Wassiliwizky et al., 2017b). Alongside variation across elicitors, there are also differences in the role of individual traits of the listener or respondent, ranging across traits such as openness to experience, agreeableness, extraversion, neuroticism and reward sensitivity (Colver & El-Alayli, 2016; McCrae, 2007; Mori & Iwanaga, 2015; Nusbaum & Silvia, 2011; Starcke et al., 2019; Sumpf et al., 2015). Yet another level of variation and inconsistency is documented with regards to psychophysiological patterns of activity during chills, including skin conductance (Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Craig, 2005; Grewe et al., 2007; Rickard, 2004), heart rate (Guhn et al., 2007; Salimpoor et al., 2009; Sumpf et al., 2015) and skin temperature (Blood & Zatorre, 2001; Guhn et al., 2007; Salimpoor et al., 2009; Sumpf et al., 2015; Wassiliwizky et al., 2017a). Relatedly, some inconsistent reports regarding brain activity before and during chills are presented across work by Salimpoor et al. (2011) and Wassiliwizky et al. (2017b). Finally, there is a level of variation with regards to accompanying bodily activity linked to chills. Mori and Iwanaga (2017) emphasise a distinction between chills and tears, whereas

Wassiliwizky et al. (2017a) describe a co-occurrence of goosebumps and tears; moreover, goosebumps may be accompanied by feelings such as a warmth in the chest (Algoe & Haidt, 2009), or a lump in the throat (Fiske et al., 2017). Some chills experiences may further be comparable to the phenomenon of ASMR (del Campo & Kehle, 2016).

Developing from the several levels of variation across musical and aesthetic chills research, two central theories have been extended and formalised in the current chapter, labelled vigilance theory and social bonding theory. Interestingly, these two theories of chills appear applicable in the context of music listening; however, each theory, when taken in isolation, struggles to encapsulate the variability of the chills phenomenon within music listening scenarios, and across other aesthetic engagements. This is a crucial shortcoming across current theoretical approaches, and any useful and representative perspective needs to accommodate the variability of results across chills research more extensively.

Given the variability across elicitors of chills, roles of individual differences, psychophysiological responses, neurophysiological activity and accompanying bodily reactions, there is a highly crucial question regarding the current conceptualisation of chills that might inform theoretical perspectives, namely whether chills reflect a unitary indicator of peak pleasure, or a collection of psychologically distinct experiences.

3.6.1 Preliminary Evidence

As highlighted earlier in the literature review, chills are often approached either as a useful, objective indicator of emotional experience in experimental settings (Rickard, 2004), or considered as an index of peak moments of pleasure (Blood & Zatorre, 2001;

Ferreri et al., 2019; Salimpoor et al., 2011). Generally, chills are treated as a unitary psychological construct, but given that there are at least two potential, distinct routes of induction for the response, related to either threat-signalling or thermoregulation functions of goosebumps, and that neither route fully explains the extant research on chills, it is possible that there are phenomenologically distinct chills experiences derived from these differing psychological processes. These distinct chills may feel differently emotionally, have separable physiological markers, and be experienced by different people at varying frequencies. If this is the case, then the entirety of existing research on musical chills would need to be reconsidered and reconciled, with a possible outcome being a better understanding of the inconsistencies surrounding the phenomenon.

The issue of how chills are currently conceptualised is exemplified by a closer look at existing research. Firstly, it has been documented that in relatively ‘safe’ contexts (i.e. no danger or harm), depending on the stimulus, listeners can also experience negative chills. As previously noted, Halpern et al. (1986) asked participants to listen to various ‘chilling’ sounds, with some of the most unpleasant sounds including scraping on a slate surface, and rubbing two pieces of polystyrene foam together. Similarly, Grewe et al. (2010) showed that chills were experienced across auditory, tactile, visual and gustatory domains, and that the accompanying emotional experiences differed notably across these stimuli, although these differences were not strongly related to sensory modality.

Besides a basic distinction between positive and negative chills responses, the idea of different types of chills is not a new one, and has been alluded to on several occasions. Panksepp (1995) noted a possible distinction between chills with happy and sad music, stating:

'[…] *it remains possible that the shivery feeling induced by happy music is, in fact, different from that induced by sad music* […]' (pp. 193-194).

From a philosophical perspective, Levinson (2006) also highlighted the possibility of variations in the chills phenomenon, depending on the musical features that elicit the response:

'[…] *there are really two kinds of musical frisson that need to be distinguished. On the one hand there are those, of relatively short duration, that are essentially timbrally and/or dynamically induced, that is, produced by sound quality as such* […] *On the other hand there are those, of relatively long duration, that are for the most part melodically/harmonically/rhythmically induced, that is, produced by sound structure as such.'* (p. 230).

More recently, Pelowski et al. (2017) suggested that the current chills phenomenon may be instead be split into two categories, labelled chills and thrills respectively. In this formulation, chills are related to concepts of harmony, flow and resonance; in contrast, thrills are linked to novelty, surprise and tension. It is interesting to note that this distinction maps quite neatly on to the vigilance theory (i.e. novelty, surprise and tension) and social bonding theory (i.e. harmony, flow, resonance) of chills.

Although the possibility of distinct categories of chills experiences has been occasionally mentioned, very rarely has an empirical approach been taken to the topic. Currently, one series of studies has explicitly assessed the chills construct (Maruskin et al., 2012). This work addressed the more fundamental issue of whether chills represent a coherent psychological construct, noting numerous limitations in existing research, such as a predominance of chills studied in response to pleasant music, and a consequent marginalisation of the response as aesthetically grounded, as opposed to representing more general psychological processes. Across these studies, Maruskin et al. (2012) presented preliminary evidence for what is essentially a distinction between two chills constructs of opposing valence, either positive or negative. In the first study, participants were asked to describe the sensations of chills experiences, with a cluster analysis proposing a two-cluster solution of the results, labelled *goosetingles* and *coldshivers* respectively. The goosetingles cluster was comprised of descriptors including goosebumps, tingling and tickling sensations, and feelings of the hair standing on end; in contrast, the coldshivers cluster included descriptions of shivers, slight quivers, tremors or shakes, and coolness or cold. Progressing from this, goosetingles and coldshivers were assessed in relation to individual traits, including the big five personality traits (McCrae & John, 1992), approach and avoidance temperaments, and whether the constructs were positive or negative in emotional character. Results suggested that goosetingles were modestly predicted by extraversion, approach temperament and positive emotionality, whereas coldshivers were modestly predicted by neuroticism, avoidance temperament and negative emotionality. Following this, further participants were asked to recall experiences of either goosetingles or coldshivers, and to rate the experience in terms of discrete emotion labels; findings indicate that compared to coldshivers, gooestingles were significantly more enjoyable, involved more surprise and involved significantly lower feelings of disgust and fear. As a final pertinent result from this set of investigations, an attempt was made to link the two proposed chills constructs to different categories of elicitors through a diary study. Interestingly, goosetingles were linked to aesthetic beauty and sexual attraction or arousal, whereas coldshivers were linked to affiliation and achievement threats.

Overall, these results suggest that the conceptualisation of chills is a foundational issue that urgently needs addressing, especially in the context of aesthetic engagement. Whilst assessing the chills phenomenon more broadly is crucial to understanding why they occur, the distinction proposed by Maruskin et al. (2012) between positive approach chills and negative avoidance chills does not appear to be adequately nuanced to explain the variety of circumstances in which chills occur with music. These experiences, elicited by numerous different characteristics in aesthetic stimuli, are generally pleasurable responses, and so there may instead be a distinction to be made at a level different from valence, for example at the level of underlying psychological mechanisms of vigilance or social bonding.

3.6.2 Subjective Feeling and Psychophysiological Differences

Central consequences of distinct chills experiences include the encapsulation of possible variations of subjective feeling, emotional quality, and physiological responses across chills reports in extant and future research. In other words, the psychological experience of chills may vary depending on whether musical chills are elicited through vigilance mechanisms or social bonding processes.

Although currently conjecture, chills elicited through vigilance mechanisms, from a crescendo in music for example, might be characterised as high arousal experiences, described by listeners in terms of activation, novelty, exhilaration and awe. Furthermore, given the fight-or-flight functionality underlying these goosebumps reactions, substantial sympathetic nervous system activity might be expected, possibly in the form of skin conductance increases. In contrast, chills elicited through social bonding processes, by lyrics or the human voice in music for example, may be characterised as lower arousal experiences, described by listeners in terms of being moved, touched, nostalgia and bittersweet feelings. Given the thermoregulatory functionality underlying these goosebumps responses, it might be less intuitive to anticipate substantial sympathetic nervous system activity; however, given the growing evidence linking body temperature to social connectedness and closeness (IJzerman et al., 2012; Inagaki & Eisenberger, 2013; Inagaki & Human, 2019; Inagaki et al., 2016), a possible marker of chills derived from social bonding might be an increase in skin temperature. An additional, important note is that as chills have been found to occasionally co-occur with other reactions, such as tears (Wassiliwizky et al., 2017a), warmth in the chest (Algoe & Haidt, 2009) and a lump in the throat (Fiske et al, 2017), these accompanying bodily responses may further suggest distinctions between chills responses derived from vigilance or social bonding processes.

3.6.3 Individual Differences

There are additional implications of distinct musical chills experiences for the role of individual differences, particularly in accommodating the variable results in the previous literature; for example, certain personality traits of listeners may be associated with the incidence of specific types of chills experience, as opposed to the frequency of chills reports overall, the main unit of analysis in existing work (Colver & El-Alayli, 2016; Nusbaum & Silvia, 2011).

Whilst a plethora of individual differences likely affect the instances of chills with music, an existing empathising-systemising model of differing cognitive processing styles maps intuitively on to the current theoretical distinction between vigilance and social bonding induction routes of chills (Baron-Cohen & Wheelwright, 2004); as a result, this model serves as an intuitive starting point for speculating about individual differences and distinct musical chills. In the empathising-systemising model, people who are labelled *empathisers* tend to process stimuli, interactions or events at the socio-emotional level, more readily identify emotions in other people and stimuli, and respond to these events in emotionally appropriate ways. In contrast, systemisers tend to process events and stimuli in terms of their formal structures, regularities, repetitions, patterns and rule systems. Research has suggested that in neuro-typically developing populations, most people demonstrate a balance between these cognitive processing styles. Pertinently, recent work has incorporated this theoretical distinction in the context of musical preferences (Greenberg, Baron-Cohen, Stillwell, Kosinski & Rentfrow, 2015). Using an updated factor structure of musical preferences (Rentfrow, Goldberg & Levitin, 2011), the authors found that empathisers preferred music that that was mellow (soul, soft rock, R&B), whereas systemisers preferred music that was intense (punk, hard rock, metal). In addition to this, Greenberg et al. (2015) found that empathisers preferred low arousal music that was gentle and sensual, sad music, and music with greater emotional depth (thought-provoking, poetic); alternatively, systemisers preferred high arousal music that was strong, tense and thrilling, of positive valence and notable complexity. Although musical chills were not the focus in this study, the findings highlight and support a neat mapping of the empathising-systemising distinction to the two theories of musical chills; more explicitly, empathisers may more readily experience chills with music that emphasises narrative, social themes and emotional depth, whereas systemisers may tend to experience chills in moments of structural contrast and change, such as crescendos and syntactical violations of expectancy.

3.6.3 Overlap Between Awe and Being Moved

When considering the vigilance theory and social bonding theory of musical chills, an initial distinction made in this chapter regarding subjective feelings of the resultant experience is that of awe and being moved; awe was suggested to be linked to vigilance mechanisms, and being moved to social bonding processes. However, awe and being moved are not entirely unrelated in the existing literature, and although the two concepts sometimes appear to oppose one another, the two may also be reconciled in other ways, adding complexity to the two theories of musical chills, and proposition of subsequent distinct chills experiences.

Traditionally, awe has been linked to the need for cognitive accommodation and the perception of vastness (Keltner & Haidt, 2003), may involve aspects of threat and fear (Gordon et al., 2016; Keltner & Haidt, 2003), and can be conceptualised in terms of subordination to a perceived event, person or object, sometimes leading to a perceived 'small self' (Campos et al., 2013; Preston & Shin, 2017); examples of elicitors may include the majestic beauty of nature (Cohen, Gruber & Keltner, 2010), or the admiration of great heroes (Shiota et al., 2007). Awe also appears to be distinct from other emotional experiences, recently supported in a cross-cultural paradigm (Razavi et al., 2016). However, research suggests numerous similarities between awe and being moved. Although awe has been linked to fear and threat, Keltner and Haidt (2003) referred to an earlier type of *primordial awe*, that functioned as a way of reinforcing social hierarchies such as enabling subordination to higher ranking individuals, therefore allowing assimilation into social systems. Over time, features of a high-ranking individual (power, vastness, eliciting the need for accommodation or cognitive schema change) may have generalised beyond social hierarchies to nature, natural disasters, and aesthetic objects such as music. The proposed social functions underlying awe has been supported more recently. Awe has been characterised as a collective emotion that serves to diminish a sense of self and encourage assimilation and oneness with broader social identities (Spears et al., 2011); awe has further been linked to prosocial behaviours such as generosity (Piff et al., 2015) and humility (Preston & Shin, 2017; Stellar et al., 2018); finally, Stellar et al. (2018) has proposed that awe refers to a family of states including elevation, admiration and appreciation.

The social underpinnings of awe closely align with those of being moved, and the adjacency of these emotional states in aesthetic experiences has been acknowledged by Konečni (2005). However, there are two reasons to suspect that there are sufficient levels of separation between awe and being moved. Firstly, whilst awe and being moved are associated with social underpinnings and functions, the two emotions sit in theoretical opposition to each other. In the kama muta formulation, being moved is indicative of intensified CSRs, and the establishment of social equivalence and sameness; in contrast, awe is indicative of social difference, subordination and the assimilation into social hierarchies. Put simply, being moved emphasises social sameness, and awe focusses on social difference, though both emotional states may serve to improve navigation of the social world. Secondly, it is worth noting that common conceptualisations of awe indicate the importance of threat or fear (Gordon et al., 2016; Keltner & Haidt, 2003; Shiota et al., 2007); most accounts of being moved bear no such implications, the closest aspect perhaps being empathic concern (Zickfeld et al., 2017). Therefore, it appears that there are some grounds to maintain a distinction between awe and being moved, particularly in the context of the vigilance theory and social bonding theory of musical chills; however, it is important to acknowledge the overlaps between the emotional concepts throughout this dissertation.

3.6.4 Summary

When focussing on the substantial variations across chills experiences reported in the extant literature, and the divergence between vigilance theory and social bonding theory, it does not appear intuitive to suggest that chills reflect a unitary psychological construct; instead, there may be important and meaningful distinctions to be made between different chills experiences (Levinson, 2006; Panksepp, 1995; Pelowski et al., 2017), derived from differences in phenomenology, physiology, personality, and psychological processes or mechanisms linked to vigilance or social bonding. Chills responses may not be a uniform indicator of peak pleasure, but a set of emotionally distinct experiences, reflecting different underlying, evolutionary processes, such as threat signalling or thermoregulation. However, as empirical work on this specific topic has only just begun (Maruskin et al., 2012), these considerations are necessarily speculative and conjectural; however, it is important to approach and interpret the data collected in this dissertation with this crucial possibility in mind.

3.7 Limitations of Existing Research

Across the current literature review on musical chills and aesthetic chills more broadly, there are three pertinent summaries to be made. Firstly, correlational research on musical chills has often reported relationships between the experience and musical structures or characteristics (Grewe et al., 2007; Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991); further associations have been highlighted between chills and psychoacoustic features (Grewe et al., 2007; Guhn et al., 2007; Nagel et al., 2008). Musical chills have also been linked to the personality trait of openness to experience (Colver & El-Alayli, 2016; McCrae, 2007; Nusbaum & Silvia, 2011), whilst listening contexts likely play a role (Egermann et al., 2011; Nusbaum et al., 2014). Beyond music, chills have also been studied in response to audio from films (Benedek & Kaernbach, 2011), film clips (Wassiliwizky et al., 2015), poetry (Wassiliwizky et al., 2017b), and other sensory stimulation (Goldstein, 1980; Grewe et al., 2010).

The second summary to make is that numerous ideas have been posited to explain the experience of musical chills, with two central theories developed in this chapter. The vigilance theory of chills, originally proposed by Huron (2006) and formalised here, suggests that music can elicit goosebumps via threat-signalling functions, involving mechanisms of expectation, brain stem reflexes and auditory looming (Ghazanfar et al., 2002; Juslin & Västfjäll, 2008); this process may result in emotional states such as awe. In contrast, the social bonding theory of chills, utilising the ideas of Panksepp (1995) and Fiske et al. (2017), suggests that music can elicit goosebumps via thermoregulation functions, given neuroanatomical overlap between socio-emotional and thermoregulatory systems in the brain (IJzerman et al., 2015; Inagaki & Eisenberger, 2013; Panksepp, 1998; Panksepp & Bernatzky, 2002); this process is suggested to be linked to the intensification of CSRs, and may be linked to states of being moved, kama muta, elevation and nostalgia.

The final summary to make is that given the substantial variability documented across research on chills, in the form of stimuli and stimulus qualities linked to chills, psychophysiological patterns of activity during chills, the role of individual differences, and the theories of chills, it seems highly difficult to approach chills as a unified psychological construct indicative of peak pleasure or emotion.

Instead, there may be numerous, distinct types of chills experiences depending on the psychological routes of induction activated by aesthetic stimuli. This idea is not new (Levinson, 2006; Panksepp, 1995; Pelowski et al., 2017), but has only been explored empirically once (Maruskin et al., 2012), and never in the context of music. Therefore, it may be that both the vigilance theory and social bonding theory of musical chills are applicable under the right circumstances, depending on the music being listened to, individual qualities of the listener, and listening contexts; additionally, each theory may predict different types of chills experiences.

Given the three brief, summarising points of the central characteristics of existing literature on the chills phenomenon, it is essential to highlight that, somewhat mirroring these summaries, there are at least three substantial limitations in current research that severely limit the current understanding of musical chills, and require urgent attention as part of the present dissertation. The first of these concerns the current characterisation of the chills response. Most existing research has referred to, or utilised, the chills phenomenon as an indicator of peak moments of pleasure or emotion (Blood & Zatorre, 2001; Ferreri et al., 2019; Grewe et al., 2007; Rickard, 2004; Salimpoor et al., 2011). However, whilst chills may, in some cases, be accurate indicators of high emotional arousal, these experiences likely have emotional qualities beyond arousal that are important to explore in research. On the contrary, almost no work has asked listeners the simple question of how they might describe the emotional qualities of the chills they experience; only on rare occasions do studies highlight a certain emotional description of chills, with the response sometimes labelled as happy or sad in everyday listening contexts (Nusbaum et al., 2014). Consequently, remarkably little is known about the emotional characteristics of musical chills; important points to consider here are whether the emotional characteristics of chills are consistent across listeners and music, and whether they are mostly positive, reflecting neuroimaging work, or more mixed, ambivalent experiences that reflect states such as being moved for example (Menninghaus et al., 2015; Wassiliwizky et al., 2015).

The second crucial limitation in the previous research is that every study that proposed or highlighted relationships between chills and musical structure has been correlational in design. Up to now, no causal approach has been adopted with musical chills, and as a result no theory of the experience has been tested. This is particularly damaging to the research field, as whilst numerous correlations have been repeatedly reported in the literature, the understanding of musical chills has barely progressed; it remains unclear as to why and how music elicits these responses, and these questions cannot be answered without developing a causal manipulation paradigm, for example where music is manipulated in some way to affect chills in listeners. This is a necessary, essential step to be taken, moving beyond correlational research to causal testing of existing hypotheses, such as vigilance theory and social bonding theory.

The final substantial limitation in existing research relates to the emotional characterisation of chills, theories of the response and conceptualisation of the phenomenon. Given the notable lack of knowledge regarding emotional qualities of musical chills, absence of causal approaches to underlying theories of the response, and considerable variability across results in previous research, it is currently unclear as to whether chills reflect moments of peak arousal and pleasure, or denote a set of distinct psychological experiences. Consequently, it is difficult to interpret the existing literature on musical chills, when no study adequately specifies the phenomenon being studied. It is notably difficult to develop future research on the topic, without exploring and refining the chills construct.

3.8 Rationale for the Following Studies

The overall summaries of existing musical chills research, and corresponding limitations that require attention, serve as the current, central foundations of the studies in the present dissertation. Specifically, this project aims to investigate and understand the emotional qualities of musical chills experiences, and to provide the first attempts at causally manipulating the response, with the aim of testing existing theories. As a possible, natural consequence of pursuing these goals, the conceptualisation of the chills construct will also be explored, mainly from the perspective of whether chills can still be reasonably approached as a unified indicator of peak pleasure, or instead as a set of distinct experiences that reflect the differing theorised mechanisms and processes underlying the response.

To conclude the current literature review chapter, it is essential to state formally the three main research questions of this thesis:

- What are the emotional characteristics of chills, and how do they relate to a wider variety of music?
- Can chills be causally manipulated? And which theories of chills can be tested?
- Are chills a unified construct? Is there any evidence for distinct types of chills?

The following sections of the current thesis are comprised of five studies carried out over the course of the project, aimed at systematically addressing the highlighted research questions. The first serves as a broad, qualitative survey into musical chills experiences, to explore general, emotional characteristics of the response, the listening situations in which the occur, and the variety of music, including specific moments in the music, linked to the phenomenon. The second study develops and tests a causal manipulation paradigm, by removing ‘chills sections’ in pieces of music, to assess whether the chills experience can be suppressed across listeners in experimental settings. The third empirical investigation is a direct continuation of the causal manipulation paradigm, increasing the level of resolution by manipulating psychoacoustic features in two pieces of music, namely loudness and spectral brightness; these manipulations provide the first explicit test of the vigilance theory of musical chills. The fourth study considers the various findings and interpretations of the first three investigations, and aims to explore possible variations in the chills response via a web-based experiment utilising multimedia items, including music, videos, images and text. The final experiment is a culmination of the four other investigations, which attempts to distinguish, through stimulus manipulations, subjective feeling, psychophysiological response and individual differences, two types of musical chills labelled *vigilance chills* and *social chills* respectively.

4. A Survey into the Experience of Musically Induced Chills: Emotions, Situations and Music

4.1 Overview of the Study

In the current state of research on musical chills, the experience has been linked to structural changes in music (Grewe et al., 2007; Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991), individual differences of the listener (Colver and El-Alayli, 2016; McCrae, 2007; Nusbaum et al., 2011), and listening contexts (Egermann et al., 2011; Nusbaum et al., 2014; Sutherland et al., 2009). Importantly however, these strands of enquiry are mostly sparse, with correlational studies linking musical structure to chills comprising most of the research; consequently, there is little known about the general incidence and experience of chills, such as the extent of pieces and styles or genres of music linked to the response, the plethora of listening situations in which chills might occur, and the emotional qualities of the phenomenon.

The main vein of correlational work on musical chills, whilst a valuable contribution to the literature, is limited in two pertinent ways for the current chapter: Firstly, there is not enough research, alongside small participant and stimuli sample sizes in the studies, to have a broader understanding of many possible associations between musical features and chills. Secondly, and relatedly, research in this field is limited through an overuse of classical music styles and genres, which whilst effective, leads to a problematic underrepresentation of the listening habits of general populations in present times; for example, the stimuli often utilised rarely emphasise the human voice or lyrical narrative, two prominent features in most contemporary popular music, and aspects possibly implicated in the social bonding theory of chills. These issues highlight the need for a broader, foundational approach to musical chills, working with a more representative participant sample, to investigate realistic listening experiences and how chills are understood in these contexts.

The role of listening contexts in music and emotion is a prominent factor that is difficult to encapsulate, and this is reflected in large parts of the research field, including musical chills work. A few studies have assessed how musical chills are experienced in different listening contexts (Egermann et al., 2011; Nusbaum et al., 2014), but this line of investigation suffers similar limitations, mainly regarding the sparsity of research. Comparable to correlational work, a broader understanding of the various listening situations in which chills occur is necessary, especially when developing theories or plausible explanations for the phenomenon. As an example, musical chills may occur when listening alone, with others, at significant life events, with live music or recordings, and whilst performing music; understanding the prevalence of listening situations illuminates the possible interactions between intra-musical (i.e. structure) and extra-musical (i.e. memories, associations) factors of emotional experience, and how these may relate to existing theories of musical chills.

Of notable significance, as highlighted in **Chapter 3**, is the poor understanding of emotional qualities of musical chills experiences. Chills have been conceptualised, particularly within neuroimaging work, as an indicator or marker of peak pleasure (Blood & Zatorre, 2001; Ferreri et al., 2019; Salimpoor et al., 2011); however, pleasure and hedonic experience does not equate to emotional response *per se* (Juslin & Sloboda, 2010), although they are inextricably intertwined (Becker et al., 2019). From an emotional perspective, chills have been theorised to reflect states of high emotional arousal (Rickard, 2004), being moved (Benedek & Kaernbach, 2011), awe (Konečni, 2005; Schurtz et al., 2012), elevation (Haidt, 2003), and kama muta (Fiske et al., 2017). Surprisingly, despite these theories and empirical approaches, it is rare for researchers to ask the foundational question of what listeners are feeling during chills, or how they would describe the response in emotional terms. This is a central limitation in current research that has substantial implications for the understanding of musical chills. For instance, if the emotional qualities of chills continue to be ignored, then it is difficult to assess whether chills are a general indicator of emotional arousal and pleasure, or a specific emotional phenomenon; as a result, theoretical predictions and testable hypotheses are limited in their development, especially when the chills construct is poorly understood. An additional issue is that, beyond the pleasurable aspects of chills with music, it is not known as to how variable the phenomenological aspects of chills are across listeners, situations and music; in some cases, chills may be experienced as a melancholic reaction to music, and in others they may be high arousal, stimulating, exciting experiences. Indeed, existing research indicates that there are at least different configurations, or flavours, of chills response; some may be accompanied by tears (Wassiliwizky et al., 2017a), others by warmth in the chest (Algoe & Haidt, 2009), whilst others still may be separated into positive and negative valence responses (Maruskin et al., 2012). Without asking listeners how they might characterise the emotional qualities of musical chills, none of these possibilities can be effectively considered or assessed.

Considering the lack of representative research into musical chills more broadly, referring to emotional qualities of chills, listening situations in which they occur, and the pieces and musical structures linked to the response, the rationale for this first study was to develop an empirical foundation and basis for the phenomenon, aiming to address the highlighted limitations by encapsulating the broader emotional characteristics of chills, their incidence across listening contexts, and the wider, representative variety of music linked to the response. Furthermore, the potential role of individual differences was of interest, such as extending previous literature linking chills to openness to experience. Therefore, the present study aimed to ask foundational questions about musical chills, to explore in more detail and more comprehensively the important facets of the experience.

4.2 Method

4.2.1 Materials

A survey was designed to target the experience of musical chills, partitioned into three main sections. The first section collected demographic information, whether the subject had experienced chills with music, and how frequent these chills occur (‘*yearly*’, ‘*every few months*’, ‘*monthly*’, ‘*weekly*’, ‘*daily*’, and ‘*every time I listen to music*’). The personality trait of openness to experience was assessed with ten items scored from one to seven (John & Srivastava, 1999).

In the second section, participants were asked to recall a specific experience of musical chills, and to provide open-ended responses regarding the subjective feelings during the experience, the eliciting piece of music, notable musical characteristics, and the listening situation. Supplementary data for these qualitative accounts were collected in the form of experience qualia (Beerman, Trznadel, & Scherer, 2015), and underlying mechanisms of music and emotion (Juslin, 2013; Juslin, et al., 2014). For these items, pre-tests ensured that ratings were understood, and that items were refined for the purposes of the study.

In the final section, participants provided up to two more pieces of music that elicited chills, and described notable qualities, general sound and style, and if possible, specific moments that directly elicited chills. As a final question, participants were asked to explain why they believed the chills had occurred.

4.2.2 Procedure

Participants were recruited via online advertisements and a local library. In the survey, chills were defined as '*an emotional response accompanied by shivers, gooseflesh and/or tingling sensations*'; this was necessary to collect specific data, although it is worth noting that listeners may conceptualise chills differently. Participants gave informed consent, and data were anonymised (e.g. 'participant 6'); references to data in the current chapter will follow this format. The survey took ten minutes to complete, and was approved by the University Ethics Committee; upon completion, participants could enter a draw to win one of three £20 Amazon gift vouchers.

4.2.3 Participants

The survey was completed by 375 participants (mean age = 36.14, range = 18 to 78), with the sample comprised of 186 females, 183 males, and six transgender or other. Finally, 206 participants reported not playing any musical instrument. Participants were recruited across various social media platforms (e.g. Facebook, Twitter), and at a local public library.

4.2.4 Analysis

Quantitative data were analysed in R. Qualitative responses were subject to thematic analysis (Braun & Clarke, 2006; Castleberry & Nolen, 2018): Raw data were coded in terms of relevance for the study, with codes grouped into themes of similarity and association; next, themes were further categorized and grouped into broad top level themes that best represented the data. Data were coded in categories of *subjective feeling*, *listening situations*, *overall music qualities*, *general sound and style of music*, *specific chills moments*, and *explanations of the chills response*. Thematic analysis was accommodated by NVivo software (Version 11.2.2). For inter-coder reliability, a random subset (20%) of responses were coded by another annotator based on the categories established; these codes were largely congruent, yielding Cohen's kappa of .72 (p <.001).

4.3 Results

4.3.1 Descriptive Statistics

The first section of the survey showed that 94% of participants had experienced musical chills; the remaining 6% of participants reported never having experienced musical chills, and were omitted from further analysis. It is important to note however that this is not an accurate indicator of overall chills prevalence in a population, as survey advertisements likely attracted those listeners who had experienced chills with music. For most participants, the frequency of chills was from 'every few months' (30%) to 'weekly' (28%). The average score for openness to experience across participants was 5.17 (SD = 0.82), indicating that participants generally scored highly for this personality trait.

4.3.2 Specific Chills Experience

The second section of the survey concerned a specific recollection of musically-induced chills; of the sample, 274 participants could recall a specific chills experience. The following results encapsulate open-ended responses regarding subjective feeling and listening situations, qualia ratings of music and feelings, and ratings of underlying mechanisms within chills pieces; data referring to overall musical qualities were analysed at a more holistic level, across all pieces of chills music reported by participants.

Subjective Feeling

Participants were first asked to 'describe how they felt during the experience'. From raw data, 484 codes were grouped into broader themes, with two accounting for most responses: *emotions and feelings*, and *physical reactions* (**Figure 4.1**).

Emotions and feelings was the largest theme, showing that chills were often reported as strong emotional experiences, overpowering, and as resulting in feelings of awe. The following is an example of overpowering emotion, and a sense of losing control:

> '*I felt as though I had lost control of my emotions and had to retreat to my "special place" as I was leading a carol service at the time!*' (Participant 281)

The chills response also included states of mixed emotions and feelings of being moved:

‘*I felt a heightened sense of emotions*. *It’s often a confused sense of happiness and intense sadness*.’ (Participant 135)

‘*I was touched and moved. What can I say? The time stopped, and there was only this music and song. I didn’t cry, but I was really moved*.’ (Participant 228)

Less frequently reported were states of joy, exhilaration and sadness without mixed feelings. Whilst strong and mixed emotional states were prevalent in musical chills, results also indicate that experiences are pleasurable and positive, leading to good or improved moods in some listeners.

The second theme of *physical reactions* covers bodily activity perceived by the listener, including changes such as gooseflesh and shivers. A frequent response reported was tears, a physiological marker not commonly included in definitions of chills:

‘*Like I could soar right alongside Elphaba if I wanted to. Tears were streaming down my face.’* (Participant 18)

Other participants noted heart rate changes, feeling a lump in the throat, and warmth or tension in the chest.

Beyond the two larger themes, participants provided other responses, such as feeling engaged with the music, connected to relatable music, and empathy for characters within the narrative. The quantitative ratings of musical qualia (**Figure 4.2**) reflect main themes of subjective feeling, with experiences rated as highly moving, fascinating and positive.

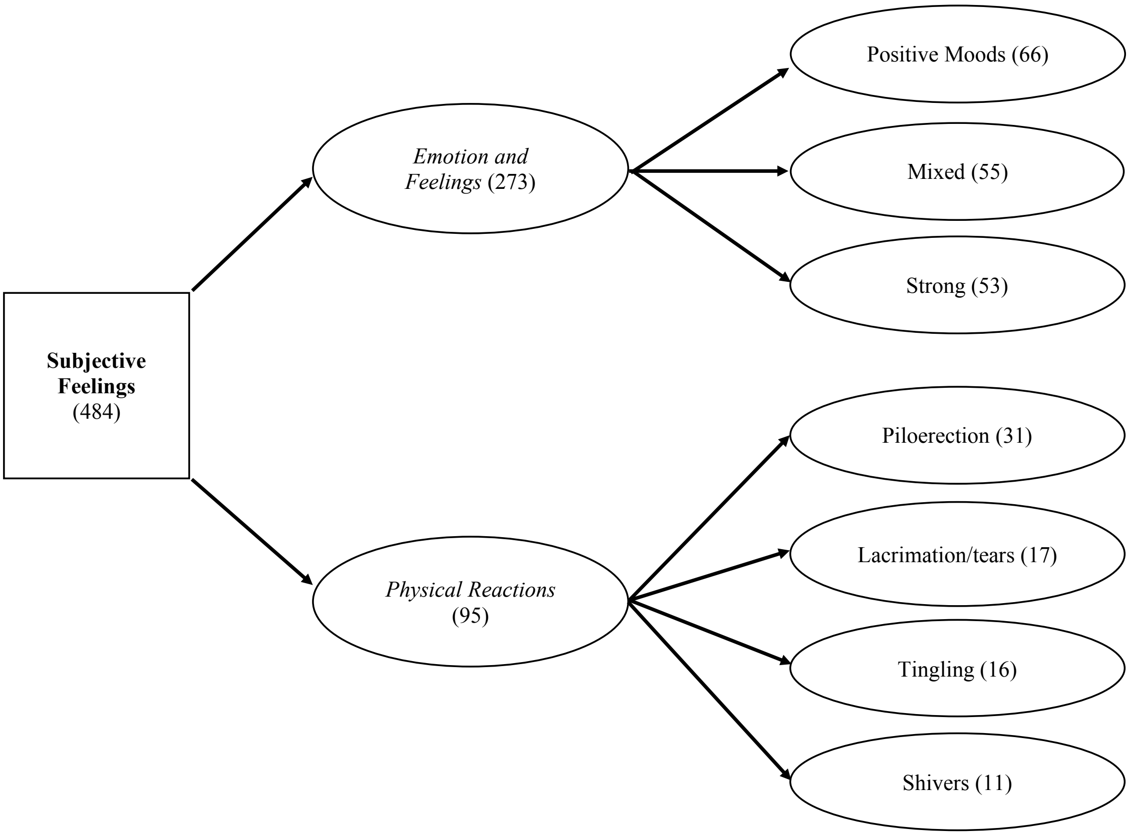

Figure 4.1: Diagram of two main themes and most frequent codes for *subjective feelings* of chills experiences; numbers in parentheses indicate number of codes extracted from the raw data.

Listening Situation

The next set of responses concern listening contexts of musical chills. From 288 codes, four main themes were developed: *social context, location, medium,* and *specific context*.

The *social context* of musical chills documents whether experiences occurred when listening alone, or with others. Results show that most chills experiences occurred when listening alone. In terms of listening with others, certain relationships were highlighted, such as listening with a partner, family or friends.

The theme of *location* suggests that chills occur in various environments, commonly at concerts, home, or during transportation (car, train, walking). Although few participants specified venues for concerts, most who did referred to cathedrals and religious settings.

The *medium* of music listening addresses modes of listening, with most participants experiencing chills whilst listening through headphones or a sound system; other ways were documented however, such as hearing music on television, or at the cinema, possibly indicating audio-visual sources as opposed to just music.

The final theme of *specific contexts* highlights idiosyncratic situations rarely mentioned by several participants, including experiencing chills whilst performing, or after a failed relationship or death of a family member.

Overall Musical Qualities

For all pieces of music reported, participants described notable and likable musical qualities. From 806 codes, seven main themes emerged: *general parameters, instrumentation, expression, interaction, lyrics, climaxes,* and *skill and artistry* (**Figure 4.3**).

General parameters involved broad references to musical aspects that were preferred, such as melodies, harmonies, rhythm and tempo. Musical expectation, change, tension and tonality were highlighted by some participants, although no clear consistencies occurred within the theme.

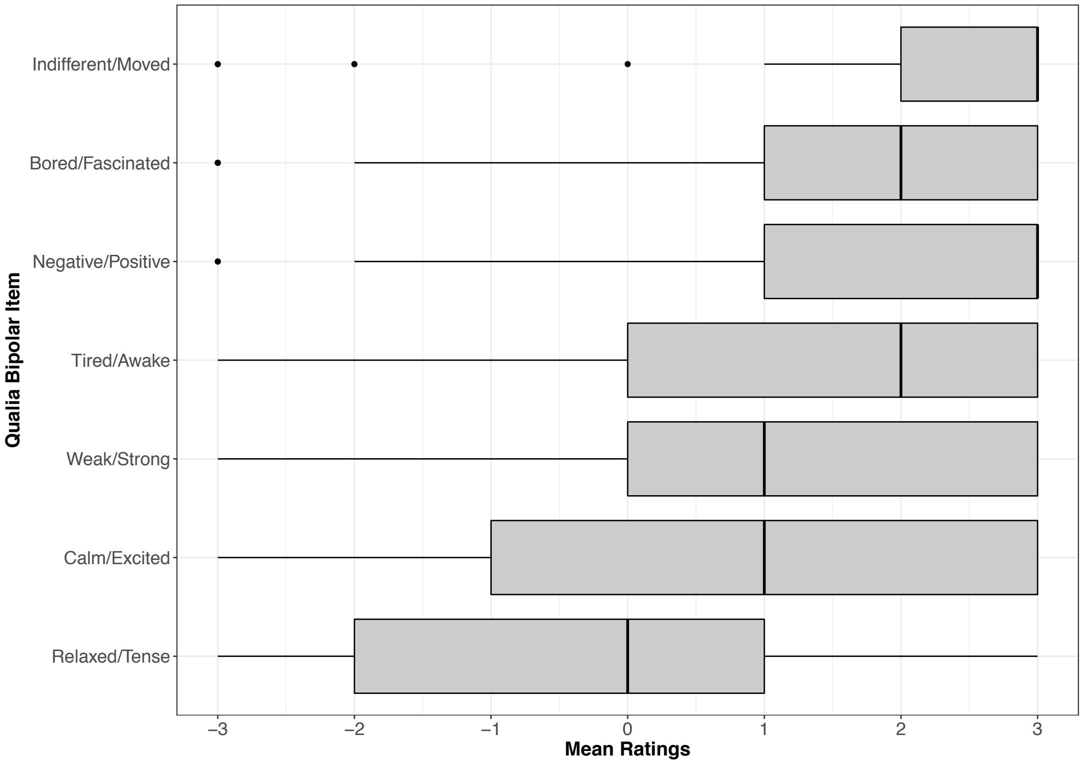

Figure 4.2: Boxplot of music qualia bipolar scales used to describe emotions and feelings within specific chills experiences (7-point scale from -3 to +3); negative scores correspond to first/left-hand word in the descriptor pairs.

With regards to *instrumentation*, the human voice was most frequently reported, which may indicate either an importance of voices in chills, or prevalence of popular music genres characterised by this feature. Other common instruments included various strings, guitars, and piano.

Expression in music was a prevalent theme, sub-divided into emotions and energy. Emotions expressed by chills music seemed to align with subjective feelings reported by participants, with mixed emotions also perceived in the music. Sadness is also reported, but contrasts with positive expressions, like hope and passion. Concepts of darkness and haunting expression were common, sometimes referring to insidious tunes. In terms of energy, most pieces were described as expressing high levels of energy.

Interaction refers to relationships between instruments, people or patterns within a piece. The most frequent aspect describes interactions between solo and accompanying instruments:

> ‘*Powerful organ, rising over the other more delicate sounds of other instruments, a very chilling, thrilling sound*.’ (Participant 280)

Closely related is the aspect of solo instruments, including guitar solos, or an instrument playing in isolation. Another common relationship is that of union, which may refer to intertwining voices or instruments, use of every orchestral element, togetherness, and comradeship:

> ‘*The sound of everyone's voices intertwining, motifs from the rest of the music coming into play, the group chants of “We are powerless”*.’ (Participant 53)

A final sub-theme of interaction refers to interplay and connections, a more direct description of relationships between instruments, performers or patterns; this includes interweaving melodies, and perceiving social interactions, such as an argument between people, a tender interplay of two people aiding each other, or general chemistry between performers.

Lyrics are of importance, but no patterns emerged, with lyrics described as cool, strong, touching, dark, religious and moving. Some narrative elements were highlighted, such as testing one’s faith, or right-wing violence.

Climaxes encapsulates peaks in music, such as crescendos and build ups. Other aspects include general swells of intensity and emotional bursts.

The final theme of musical qualities is that of *skill and artistry*, which often describes performance properties, like amazing singing, vocal range, well performed guitar solos and skilled instrumentalists. Compositional skill is also highlighted, referring to well-written music and genius.

The themes of overall musical qualities find some parallels with quantitative measures of underlying mechanisms of music and emotion (**see Figure 4.4**); for example, emotional contagion is rated higher than other mechanisms, possibly reflecting the human expression of emotion through vocal performance. Rhythmic entrainment is also rated highly, but lyrics appear less prominent in quantitative ratings, suggesting some inconsistencies between open-ended responses and quantitative data.

4.3.3 Characteristics of Chills Music

General Sound and Style

In the third section of the survey that collected additional chills pieces, participants described the music in terms of general sound, style and genre. The 438 codes were categorized into three main themes: *expression and quality*, *genre and style*, and *images and concepts*. Note that some results here share similarities with overall musical qualities previously reported.

Expression and quality refers to expressions of mixed emotion, sadness, tenderness and positive emotions. Chills-eliciting music was also reported as expressing beauty, sublimity and awe, sometimes labelled as enchanting, glorious and

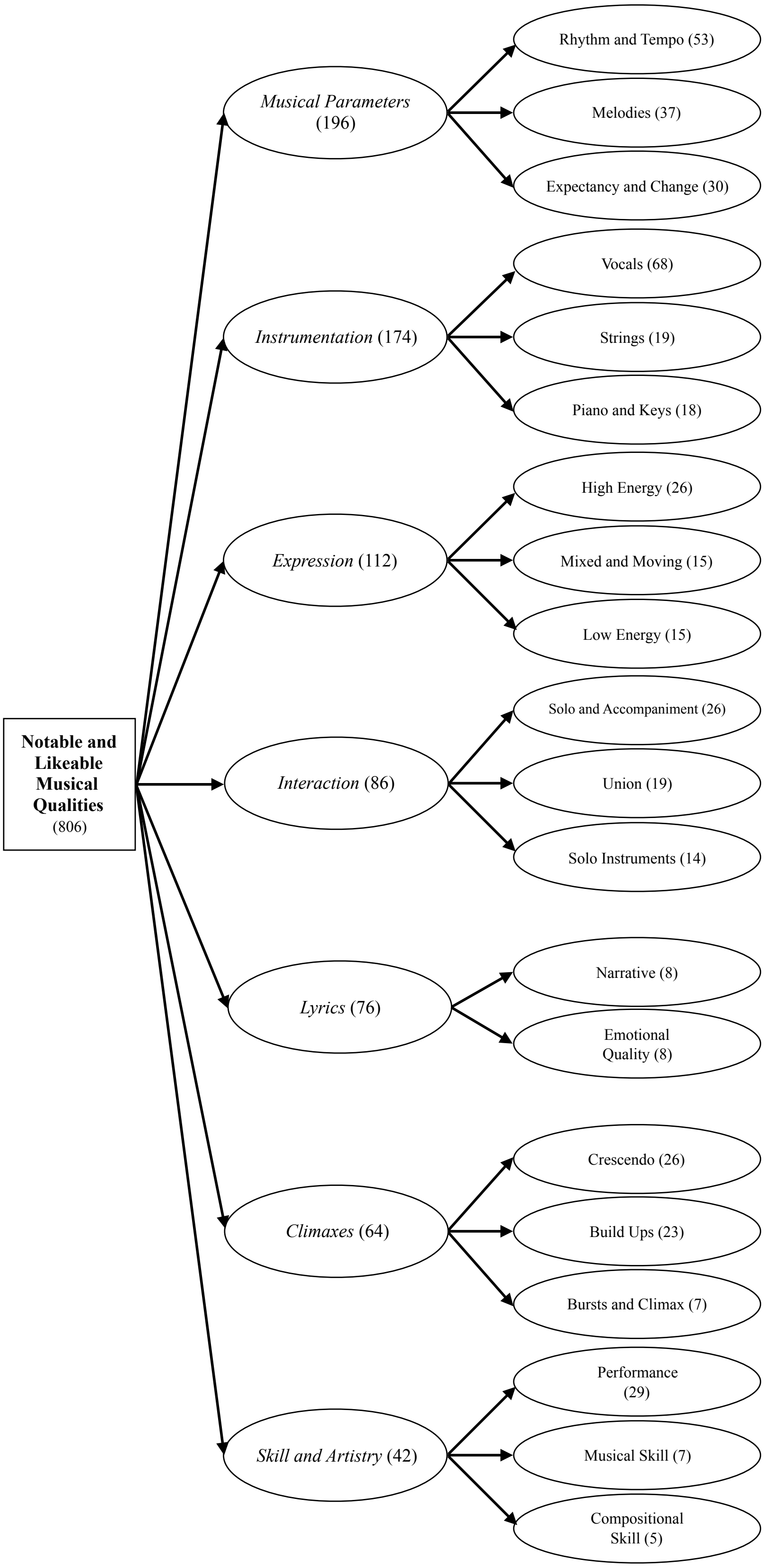

Figure 4.3: Diagram of seven main themes and most frequent codes for *overall musical qualities* of chills pieces; numbers in parentheses indicate number of codes extracted from the raw data.

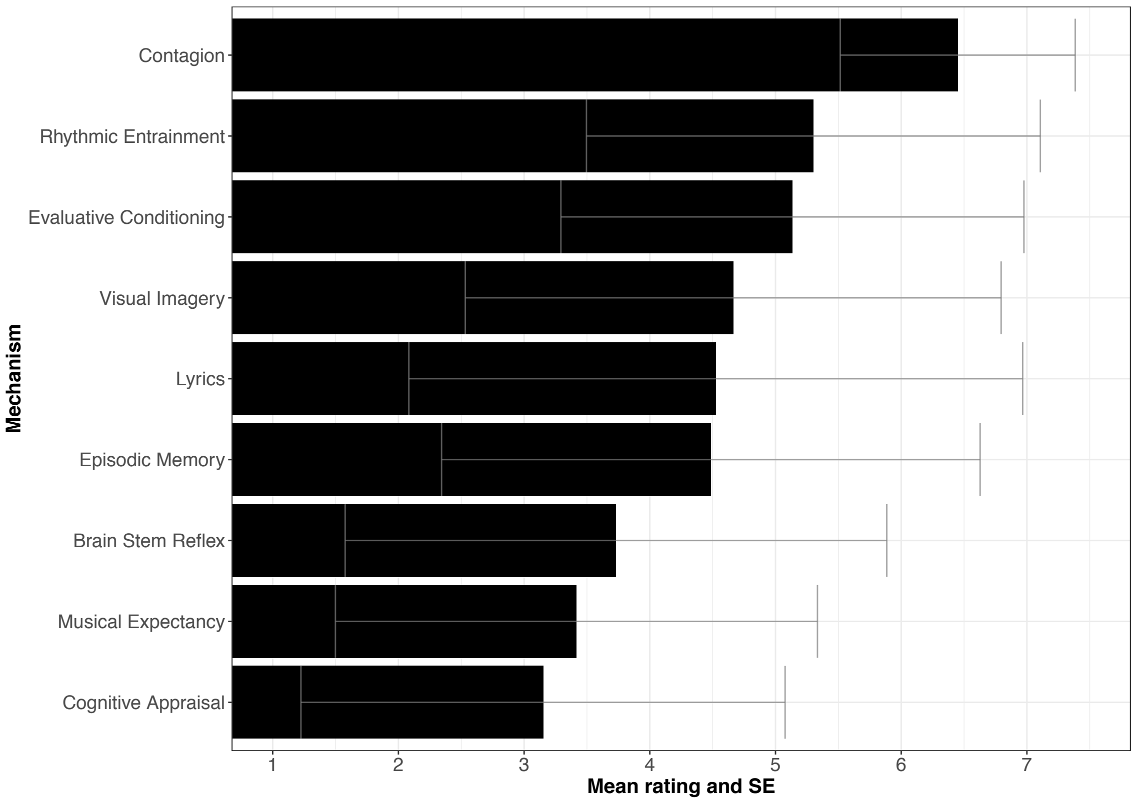

Figure 4.4: Bar chart visualisations of mean scores for reported underlying mechanisms across pieces of chills-eliciting music, on a scale of one to seven (error bars indicate standard error).

transcendental. Participants used a wide variety of descriptors when conveying the overall sound of a piece, referring to depth, fullness, catchiness, and music as an anthem.

Genre and style highlights the variety of music involved in chills. Pieces were described in terms of instrumentation, ranging from piano, fiddles and trumpets to guitars and synthesizers. Other music was described at a broader level of genre and style, with the two most reported styles defined as classical orchestral styles, and general popular styles; other genres include ballads, jazz, folk, and electronic.

Images and concepts refers to abstract descriptions of sounds within music; there are common references to heavenly, angelic sounds and the idea of God, whilst other reports portray quasi-emotional concepts such as music tugging on the listener's heart. Some listeners refer to nature, such as moonlight, the sun, waves on a shore, or unearthly sounds.

Given the similarities between questions of overall qualities and general style, some codes were identified multiple times. As a quick summary however, participants again referred to crescendos and build ups, and aspects of musical union or solo and accompaniment interaction when discussing the sound and style of chills music.

Specific Chills Moments in Music

A central question asked participants to describe the moment in a piece of music that elicited chills. From this, 153 codes were categorized into five central themes: *voice and words, entrance of instrument, peaks, musical relationships,* and *transition and change* (**Figure 4.5**).

The theme of *voice and words* appears to indicate significant elicitors of chills, with most coded data accounted for within this theme. Reports here describe the effects of lyrics, from specific lyrical lines, to broad reports of the importance of lyrics:

> *'It's definitely the lyrics that affect me most with this one, in particular: "An old man said to me, won't see another one"; "I turned my face away and dreamed about you"; and "You took my dreams from me when I first met you - I kept them with me babe, I put them with my own". Oh man, I'm listening to this again, and crying! I'm soft as clarts.'* (Participant 156)

> *'The lines: "so are we left to chance meetings, is that all we can rely on, resigned to raise glasses in anonymous cafes, reciting our failures as if we needed that proof of regret over what might have and what should have been, darling are we just good friends".'* (Participant 273)

Narratives underlying the lyrics include love, romance and sadness. The human voice is also reported to elicit chills, though descriptions are often vague, highlighting expressions of strength and anguish.

Peaks is like the previously established theme of climaxes; in this context however, participants confirm that crescendos and build ups specifically elicit the chills response. Further aspects include bursts of energy, melodic peaks and salient notes, such as high notes in a vocal or instrumental performance.

Another recurring theme is *musical relationships* and interactions:

> '*The part that almost never fails to give me chills if I'm listening attentively is near the end, where the full orchestra and choir join together for the first time. The main theme (which has been mostly cheerful and optimistic the whole time) turns dark for a few moments, as the choir is wailing. It's a very powerful moment.'* (Participant 116)

This quote describes concepts of union, highlighting the feeling of instruments and musical factors coming together to form a whole sonic object; this is often portrayed as instruments blending together, voices uniting in harmony, or a full orchestra 'crashing in'. In contrast to musical union, some participants report that minimal moments or solo instrumental lines resulted in chills, referring to guitar solos, or specific moments in music where background instruments fade out, leaving one or two instruments playing alone. A final aspect of musical relationships is that of social narratives, linked to lyrics describing love, feelings of loss, and music that resembles a person's cry for help, or the idea of reconciliation.

The *entrance of new instruments* reflects moments in a piece where a new instrument or voice enters, such as guitars kicking in, trumpets taking the tune, and strings entering.

Finally, *transition and change* encapsulates moments of structural transitions or alterations. Some examples include changes in dynamics, meter, tonality, and meta-structure such as moving from a bridge to a chorus.

4.3.4 Chills Explanations

A final exploratory question asked participants to explain why they experienced chills. Some supplementary data were collected, with 308 codes grouped into three main themes of *relationships, musical parameters,* and *evoking memories*.

In the *relationships* theme, participants suggested that chills occur when the music and words are relatable, mirroring one's life or reflecting previous experiences. Music is sometimes described as speaking to the listener, offering support or comfort and sharing a personal bond and connection, whereas other participants note that empathy for a performer or character in the narrative underlies the chills response:

> '*An almost hypnotic feeling. I want to close my eyes and just feel the music all around me. That feeling of the hairs standing on the back of your neck. It's a pleasurable experience; an intense connection with the music. I can feel it now if I close my eyes.*' (Participant 261)

> *'I felt comforted by the various movements in the piece (instrumental).'* (Participant 371)

> '*I felt touched, moved. And perhaps inspired in a way, too. I think that listening to those first few lines made me realise that in a way I was like the protagonist of the song and it also reminded me of one of my favourite fictional characters.*' (Participant 9)

Finally, aspects of love and interpersonal relationships are highlighted, and how these are expressed in music.

Musical parameters is a theme comprised of varied explanations referring to specific musical features linked to chills, including build ups, climaxes and chord structures. The clearest trend however is reference to the human voice as being a common elicitor of chills.

The final theme of *evoking memories* has rarely been highlighted in the survey, but reflects extra-musical processes characterising music as a retrieval cue for emotional memories; there were no trends in the specificity of reported memories.

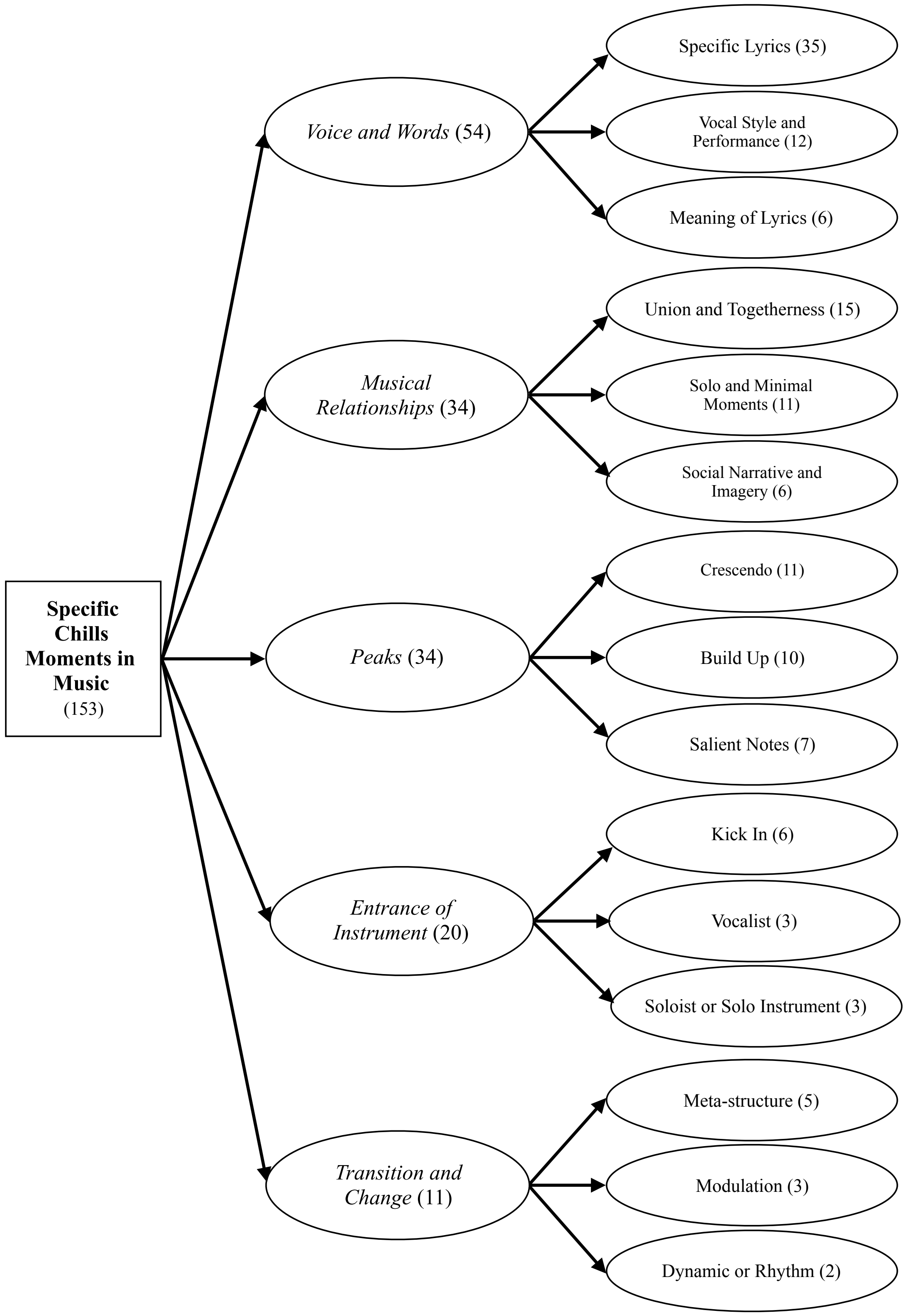

Figure 4.5: Diagram of five main themes and most frequent codes for specific chills moments in music; numbers in parentheses indicate the number of codes extracted from the raw data.

4.4 Discussion

This first study of this dissertation aimed to provide a novel, direct investigation into numerous characteristics of musically-induced chills, and the results represent an advancement in knowledge of emotional qualities, prevalent listening situations, and a larger selection of music and features that elicit chills in listeners. Generally, participants experienced chills at a frequency of every few months to weekly; furthermore, chills responders were characterised by high scores in the openness to experience personality trait, supporting previous research (Colver & El-Alayli, 2016; McCrae, 2007; Nusbaum & Silvia, 2011). Chills often occurred when listening alone, whilst concert environments were also reported frequently; interestingly, although rare, some participants reported experiencing chills whilst performing certain pieces. Participants took part from numerous locations in the world, and varied in terms of age, instrumental playing, and occupation, resulting in a more representative sample than previous investigations into chills; conversely, over 350 different pieces of music linked to chills were reported across the participants, reflecting a diverse collection of styles and genres in comparison to existing correlational work.

Central findings concern the emotional characteristics of chills, a significant limitation in existing research. Chills have been linked to peak pleasure (Blood & Zatorre, 2001), strong emotions (Gabrielsson, 2011; Rickard, 2004), and being moved (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2015). Considering this previous research, and a working definition of chills provided to participants, it is not surprising to see emotions as a central theme in the survey; however, until now the specific emotional qualities of chills had not received empirical attention. The survey collected novel data that demonstrated for the first time that musical chills are often described directly as an overwhelming, strong experience, frequently containing mixed emotions such as an amalgam of happiness and sadness; it is also worth noting that being moved or touched were the most common descriptors used by participants in their open-ended responses. These results reflect existing literature, but develop from the ideas that certain emotional states are accompanied by chills, to assess specifically how listeners describe their chills responses to music.

Of the musical selections referenced in the survey, consistencies were evident in salient musical features and specific chills moments in the pieces. The human voice was frequently noted by participants, alongside emotional expressions perceived in the music. Further features associated with chills included crescendos, swells and climaxes, linked to increases in emotional arousal that may be conducive to chills (Rickard, 2004; Salimpoor et al., 2009). Finally, chills were associated with interactions and relationships perceived between instruments, performers or characters in the music. Although dynamic changes, unprepared harmonies and the entrance of new instruments have been linked to chills (Grewe et al., 2007; Sloboda, 1991), rarely has reference been made to moments when full orchestras unite, singers blend into harmony, or larger groups of performers begin chanting. Indeed, novel data regarding musical features is portrayed in themes of musical relationships and interactions, covering aspects of unity, blending, and developing relationships between solo and accompaniment instruments (though see Guhn et al., 2007).

This first study may begin to inform theories and conceptualisations of musical chills. With regards to the vigilance theory of chills, there are certainly reported musical characteristics that may elicit mechanisms such as brain stem reflexes, musical expectancy and auditory looming, including crescendos, build ups and unexpected chord changes. These processes are mainly linked to the arousal dimension of affective response (Russell, 1980; Steinbeis et al., 2006); however, arousal levels are not sufficiently nuanced to explain the emotional experiences identified in this survey. Furthermore, the lack of a stimulus-response pattern in musical chills suggests that automatic survival mechanisms implicated in vigilance theory may not be pervasively central to the experience; to address this, investigations need to move beyond correlative work and systematically test musical chills to better understand these processes, and how they might differ across individuals. Despite these issues, crescendos and build ups were common in chills moments, reflecting most existing research (Grewe et al., 2007; Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991); any underlying processes linked to these features should be considered in theoretical contexts.

The enigmatic concept of awe has also been linked to chills (Keltner & Haidt, 2003; Konečni, 2005; Schurtz et al., 2012; Shiota et al., 2007), possibly in relation to fear and vigilance processes, although this remains unclear. Consistent features in the survey such as crescendos may be related to awe, and in fact numerous participants reported feeling overwhelmed by the music in some way, perhaps due to the perception of grandeur or feelings of subordination to the musical object. The appreciation of artistic skill and musical excellence was reported in the survey, and this interpersonal, social appreciation has previously been discussed in terms of awe and admiration, with physiological indices including gooseflesh and warmth in the chest (Algoe & Haidt, 2009). However, further research is required in characterising awe, and understanding its possible connection to chills.

Several results across this first survey may also implicate the social bonding theory of chills, linked to mixed states of being moved (Menninghaus et al., 2015) the broader concept of kama muta (Fiske et al., 2017), and intensified communal sharing relations. Numerous participants explicitly referred to feeling moved or touched, with some stating feelings of happiness occurring with sadness. Being moved has elsewhere been linked to prosocial cues and significant life events, involving social scenarios such as weddings or funerals (Hanich, Wagner, Shah, Jacobsen & Menninghaus, 2014; Menninghaus et al., 2015); some of these idiosyncratic events were described by participants, such as a piece of chills music being played previously at their father's funeral. Interestingly, the prevalence of the human voice, lyrics and musical relationships in specific chills moments suggests a role of social aspects underpinning chills. The human voice may resemble distress vocalisations that motivate social reunion (Panksepp, 1995); furthermore, the voice is innately more social, communicative and contagious than other instruments, evidenced through mirror neuron activity and perception-action loops (Davies, 2011; Molnar-Szakacs & Overy, 2006; Rizzolatti & Sinigaglia, 2016). As we better understand human action, emotional expression is strongly communicated by the voice, potentially allowing for social processes such as empathy at the level of the person or character that the voice belongs to (Clarke et al., 2015). Lyrics often describe explicit narratives, and can be relatable and understood in similar ways to literature or film; however, this prevalent aspect of modern music is often avoided, given the difficulties of understanding combined effects of linguistic and musical parameters (Ali & Peynircioglu, 2006; Fiveash & Luck, 2016). Regardless, specific lyrics quoted in the survey touched on topics of love and loss; these are often judged as relatable by listeners, highlighting the possible presence of empathic processes, social bonding, and intensification of communal sharing relations. Finally, the theme of musical relationships may be contextualised in terms of social cues and cognition, although it is unclear as to how these processes operate in complex musical situations. However, it appears intuitive to treat moments of musical union, such as full orchestras coming into the music together, as social; for example, these moments may reflect a third-person, observed intensification of communal sharing relations implicated in experiences of being moved and kama muta (Fiske et al., 2017). Additionally, interactions highlighted between solo and accompaniment instruments could be perceived in terms of interpersonal support and cooperation; Haidt (2003) suggested that the positive emotion of elevation, like being moved, is elicited by observed acts of altruism and moral virtue. Although little empirical research exists in the context of music, recent research suggests that social cues are identified by listeners in improvised duets (Aucouturier & Canonne, 2017), and perceiving these cues may be important in understanding chills as a response to social bonding, empathy and being moved. Beyond perceiving social cues and interactions in music, some participants describe experiences in which they connect or interact with the music in some way; music can comfort the listener, a listener can feel empathy for characters or identities in the music, and in various instances listeners described personal bonds with the music. This type of experience has been highlighted in the musical chills context before, with listeners having the sensation of 'being one' with the music during chills (Laeng et al., 2016). Interestingly, these accounts can sometimes be understood as listeners anthropomorphising a piece of music, and experiencing a parasocial relationship with it. This is not dissimilar from social surrogacy, in which people use images, television and music to temporarily replace social relationships in their absence (Derrick, Gabriel & Hugenberg, 2009; Gabriel & Young, 2011; Gardner, Pickett & Knowles, 2005; Schäfer & Eerola, 2018). This may be an intuitive reaction to moments of social isolation, to satisfy the need for belonging (Maslow, 1943), and in the context of social bonding theory, music as a social surrogate may be poised to elicit the chills response through intensified communal sharing relations. However, like discussions regarding structural changes and vigilance processes, further research is required to progress from theoretical conjecture. These novel results are crucial for the existing state of research on musical chills; until now, most links between chills and music were based on structural change and development, but it is evident that when referring to a different, more representative corpus of music associated with chills, including contemporary popular music for example, there are many other potential elicitors that do not intuitively fit the narrative of vigilance theory.

Although consistencies were found in the survey, there is also wide variability across participants, in terms of feelings, situations and musical moments linked to chills. Furthermore, numerous musical aspects highlighted above are not easily reconciled in terms of similarities between them; it does not seem intuitive that crescendos and lyrics activate the same psychological processes in listeners, nor does it appear that a single theory or proposed mechanism is currently capable of accommodating the variety of musical elicitors linked to chills. The current study adopted a necessarily broad approach, but given the variability of responses, it is reasonable to suggest that musical chills do not specify a singular emotional response (Levinson, 2006; Maruskin et al., 2012; Panksepp, 1995; Pelowski et al., 2017); instead, these experiences may be phenomenologically distinct, depending on whether chills are elicited by dynamic changes, lyrics, human voices, or expectancy mechanisms. Physiological activity accompanying chills varied from tears, to warm feelings in the chest; interestingly, both responses and sensations have been linked to aesthetic and social awe respectively (Algoe & Haidt, 2009; Braud, 2001). These additional physical responses, not normally encapsulated by chills, may provide important clues regarding the differences in emotional experience, especially given recent work highlighting how different emotions might be felt in varying locations of the body (Nummenmaa, Hari, Hietanen & Glerean, 2018), and proposed phenomenological distinctions between tears and chills (Mori & Iwanaga, 2017).

4.5 Summary

To conclude the first study of the current dissertation, this survey has provided the first direct investigation of musically-induced chills in terms of emotional qualities, listening situations, and the variety of music and musical features that elicit the response. In turn, three limitations have been addressed, through revealing the emotional characteristics of musical chills, understanding more broadly the situations in which they occur, and finally developing a broader, comprehensive picture of the music that can elicit chills in listeners, and the wide variety of features linked to the response. The survey highlighted various aspects of the experience, such as chills being described as strong, overwhelming, and mixed emotional states. Musical aspects including dynamic changes have been linked to chills, supporting previous literature and the vigilance theory of the response; however, much of the present data can be interpreted in terms of social cues and processes, such as empathy with performers or characters in a narrative, and perceiving social interactions within a piece of music. The human voice is often linked to chills, possibly mimicking social separation calls (Panksepp, 1995), or activating contagion and empathic processes (Juslin, 2001; Juslin & Västfjäll, 2008). Solo and accompaniment relationships are also reported as eliciting chills, which is speculatively contextualised in terms of perceiving social cues of support and cooperation between individuals or characters; these features appear to be aligned more closely with the social bonding theory of chills. Findings suggest that it may be difficult for one theory to accommodate the variety of elicitors and potential psychological processes underlying chills, reflecting the broader variation found across existing research reviewed in **Chapter 3**. Furthermore, the variability of results within the survey suggests that experiences of chills may be phenomenologically distinct from one another, and this may depend on eliciting musical features, characteristics of the listener, and the listening situation. It appears that conceptualising musical chills as a general indicator of peak pleasure is not sufficient for understanding the phenomenon.

5. Suppressing the Chills: Effects of Musical Manipulation on the Chills Response

5.1 Overview of the Study

In the previous chapter, the substantial variation across musical features and styles linked to chills was evidenced, further reflecting the extant literature reviewed in **Chapter 3**. Additionally, the numerous chills experiences, and musical aspects linked to the response, may be explained to differing degrees by several theories, including vigilance theory and social bonding theory. However, these conclusions exacerbate the second, crucial issue prevalent across existing research highlighted at the end of **Chapter 3**, concerning the absence of causal approaches to musical chills, and a predominance of correlational designs and results. Whilst these correlational studies have proved to be invaluable for understanding what kinds of musical structures and features may be well suited to eliciting chills, and have served as a foundation for some theoretical discourse around the phenomenon (Huron, 2006), the studies are relatively few in quantity, include small sample sizes, and are restricted in terms of how many different styles and genres of music are utilised, resulting in an underrepresentation of certain relationships between chills and music; this is already apparent when considering novel data presented in the previous chapter, suggesting that lyrics and the human voice were prominent elicitors of musical chills. A further, crucial point is that there currently exists no research on musical chills that has taken the necessary step beyond correlational research, to develop causal manipulation paradigms that may allow researchers to test these repeatedly documented relationships between musical structure and chills. Because of this, whilst theoretical discourse has developed, albeit slowly, no theory of musical chills has ever been causally tested, and consequently there exists a severe lack of understanding as to why the phenomenon may occur in the first place; this is especially troublesome when the previous and current findings support numerous explanations of the response, with further possible implications for how chills are currently conceptualised. By developing a causal manipulation paradigm for musical chills, the posited theories can be tested, and correlations between structure and the response can be better understood; by extension, causal testing of the specific phenomenon of chills may also serve to elucidate broader questions of how music comes to elicit intense emotional experiences.

This second study aimed to provide the first empirical attempt at causally manipulating the musical chills experience. With plans to remove previously identified sections in certain musical stimuli that elicit chills, the three main aims of the research were to: Firstly, test whether chills can be manipulated in experimental settings, serving as the first demonstration of causal approaches to the phenomenon; secondly, assess whether chills are linked to specific features, qualities and sections in music; and finally, assess how removing *chills sections* affects the frequency and experience of chills. The main hypothesis of this study was that pre-identified chills sections in three musical stimuli would result in more chills experiences and stronger emotional responses compared to other notable moments in the piece, that are either characterised by structural changes previously correlated with chills, or by their psychoacoustic similarity to the chills section. Additionally, it was expected that when removing the chills section to create manipulated versions of each piece, the frequency of chills experienced across listeners would be reduced.

5.2 Methods

5.2.1 Design

A listening experiment was carried out using three musical stimuli that were reported to elicit chills in listeners from the survey study in the previous chapter. For each stimulus, there were two listening conditions corresponding to the original version and the manipulated version of the piece, resulting in a total of six listening conditions. To create manipulated listening conditions, the musical stimuli were edited, by removing identified *chills sections* in their entirety from the pieces, and then splicing together the music from before the chills section with the music that followed the end of the section; the characteristics of the preceding and subsequent musical sections allowed for the maintenance of logical and natural progressions in the manipulated versions (see **Figure 5.1**). These chills sections were determined through participant reports from the previous chapter, combined with musicological analysis of the musical development and structure, to produce a meaningful demarcation of start and end points for the sections. To make the editing as non-disruptive as possible, sophisticated cross-fade techniques were applied to splicing points in the audio. In pilot testing, listeners unfamiliar with the pieces of music were under no suspicions that the manipulated versions of the music had been altered or modified. This method of manipulation has the advantage of maintaining high ecological validity, but comes at the cost of control over variables in the music, and higher fatigue for participants in listening to six stimuli of five to eight minutes in length. All audio editing was completed in the Logic Pro software.

The central dependent variables included a self-report of chills experiences, skin conductance levels, and continuous measurements of chills intensity. The experiment followed a repeated-measures design, with participants listening to both versions of the three musical stimuli. To limit effects of repetition and fatigue, the stimulus presentation order was pseudo-randomized for each participant, such that no version of the same piece directly preceded or followed the other, and that presentation order was different for every participant. Additionally, the experiment was partitioned into two blocks of listening, with three musical stimuli in each; these blocks were separated by a short questionnaire, extending the break between listening blocks to roughly 10 minutes.

5.2.2 Participants

All participants were selected through a pre-screening process, which involved completing a questionnaire confirming that participants had experienced musical chills before, and that the response occurred relatively frequently (e.g. monthly). A total of 24 participants took part in the listening experiment. Of the sample, 17 were female, with a mean sample age of 25.2 (SD = 5.96, range 18 to 46). For the descriptive statistics of the sample, please see **Appendix 1**.

5.3.3 Materials and Measures

Self-report items

For every piece that participants listened to, a series of rating scales were completed. Immediately after each piece, participants were asked to do the following: Firstly, confirm whether they experienced chills whilst listening (yes/no); secondly, rate how they felt across 11 emotional descriptors derived from the Geneva Emotional Music

Scale (GEMS) on scales of 1 to 7 (Zentner et al., 2008); thirdly, rate the intensity of their emotions and how moved they were (Likert-type, 1 to 7); finally, complete an updated experimental version of the MecScale (Juslin et al., 2015; Juslin et al., 2014) to assess the potential significance of underlying mechanisms in the chills experiences (Likert-type, 1 to 7). This instrument was updated, following some inconsistencies with the original version when compared to corresponding qualitative data in the survey from the previous chapter. For the GEMS and MecScale descriptors, the order of presentation in the questionnaire was shuffled in the second block of listening to limit effects of fatigue and automaticity of responses. Finally, after each block of three stimuli, participants were asked to rate how much they enjoyed each piece, how familiar they were with the music (1 to 5, corresponding to statements of the degree of familiarity), and to describe their favourite moment in the piece. Finally, individual differences such as musical sophistication were collected using a reduced version of the Goldsmith's Musical Sophistication Index (Müllensiefen, Gingras, Musil & Stewart, 2014), an instrument linked to aspects of aptitude and musical skill, but also to more broad interactions and engagement with music; musical preferences were captured using the short test of musical preferences (STOMP; Rentfrow & Gosling, 2003).

Stimulus selection

The selection of the musical stimuli was informed by the survey on musical chills in the previous chapter. In total, three pieces were chosen as stimuli for the experiment in accordance with a set of criteria: Firstly, the piece of music needed to be highlighted independently by two or more participants in the survey; secondly, participants had

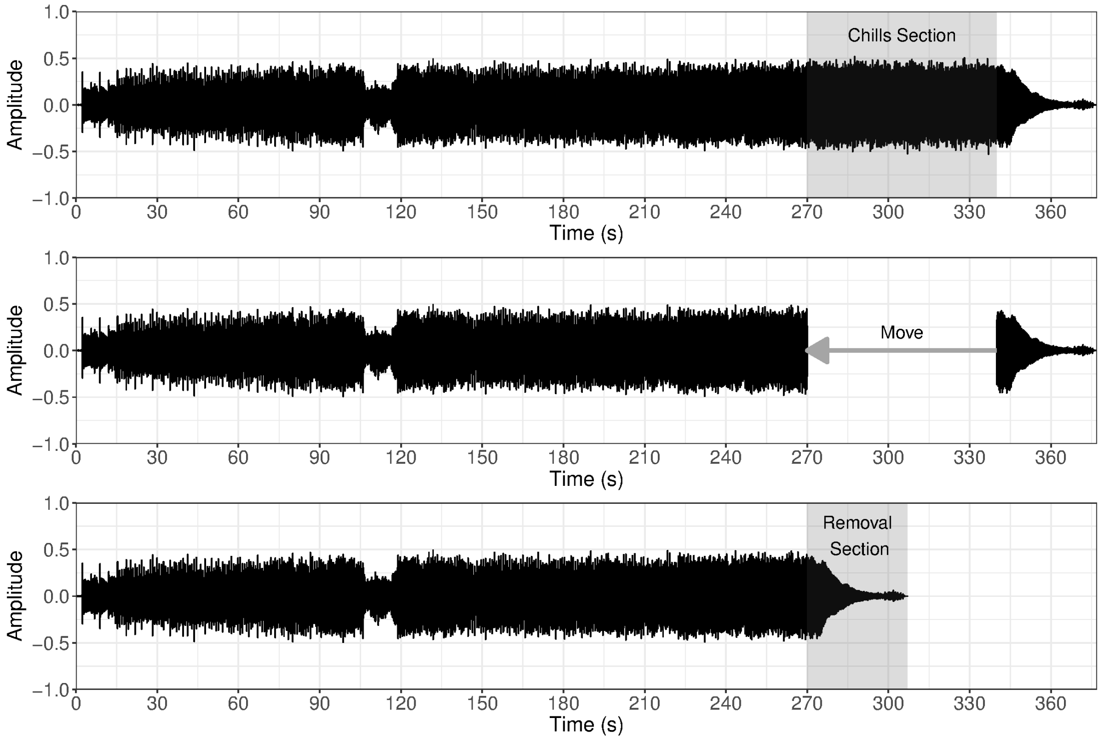

Figure 5.1: Example of the audio editing procedure to create manipulated stimuli. First, the *chills section* is identified; second, the chills section is removed from the piece; thirdly, the music following the chills section is moved and spliced with the music that came before, resulting in what is termed the *removal section*. The figure depicts the piece *Glósóli* by Sigur Rós.

to be able to determine and independently agree on a specific moment in the piece that elicited chills; thirdly, the piece needed to be suitable for manipulation and audio-editing processes (smooth, natural progression following manipulation); and finally, the stimulus would need to be of a usable duration (no longer than nine minutes), to control for the length of the experiment and possible differences in results because of stimulus duration, and to minimise participant fatigue.

Resulting from the selection process and criteria, the first piece selected was *Glósóli* by Sigur Rós. The piece can be described as belonging to a rock or post-rock style with Icelandic lyrics, with a focus on atmosphere and texture developed by electric guitars. Structurally the piece is quite simple, utilising two different chord progressions and a long build-up to what has been specified here as the '*chills section*', namely a crescendo and dynamic climax of distorted guitars and loud drums, starting at 4:34. The second stimulus selected for the experiment was *Jupiter* by Gustav Holst. The piece belongs to a larger orchestral suite, and is instrumental, upbeat and energetic. The chills section identified in this piece was a slower, thematic string progression in the middle of the piece, beginning at 3:09 and ending at 4:55. The melody of this section has elsewhere been adapted to lyrics, and used in international sporting events, and so may be well-known by listeners, regardless of familiarity with the overall piece. The final stimulus selected from the survey was *Ancestral* by Steven Wilson, an electronic progressive rock piece characterised by a large shift from electronic ambience to more traditional hard rock instrumentation. The original piece is over 13 minutes in length, and was shortened to 6 minutes for current purposes, justified by no reports in the previous survey of chills occurring in the second half of the piece; care was taken to make sure the music sounded complete, and that the shorter version did not end abruptly. The chills section reported for this piece was during a guitar solo towards the end of the piece, starting at 4:02 and ending at 5:02. A final aspect to note is that Ancestral was the only piece to contain English lyrics, which may affect the listening experience (Ali & Peynircioglu, 2006). Both Glósóli and Ancestral were assessed *a priori* to be unfamiliar pieces of music, further confirmed by ten other listeners in a pilot test, whereas Jupiter was predicted to be more familiar; experiment results thoroughly support these assessments. Detailed time stamp information for all sections reported in this study can be found in the corresponding open access dataset (see **List of Publications** section).

5.3.4 Chills Measurement

To capture the experience of musical chills, participants reported the intensity of their chills whilst listening using a continuous rating paradigm, and their skin conductance was recorded. Skin conductance was preferred as it is a non-intrusive procedure, which is important when considering strong emotions in laboratory settings; additionally, the measure has been frequently utilized as an indicator of chills in previous research (Benedek & Kaernbach, 2011; Craig, 2005; Grewe et al., 2007). Skin conductance data were captured with two electrodes (Ag/AgCL) attached to the distal phalanx of the index and middle fingers of the non-dominant hand with the NeXus-10 MKII and BioTrace software.

As skin conductance is only indicative of emotional arousal, continuous subjective measurements were also used. For these continuous measurements, data were collected with an analogue slider, moved upwards to indicate higher levels of chills intensity, and vice-versa; slider movement changed amplitude values of a monitored and recorded sine wave, which was preferred over multidimensional continuous rating scales, as it was deemed to be less distracting, and a simpler task for participants. It was important to keep this task as simple as possible, as concurrent tasks during listening may have the capacity to affect physiological and emotional responses (Jäncke, Leipold & Burkhard, 2018). Chills are normally reported by participants, either by raising their hand to indicate the response (Craig, 2005; Panksepp, 1995) or by pressing a button (Grewe et al., 2007; Salimpoor et al., 2009). Whilst convenient for analysis and assessing the frequency of chills within a piece, it is possible that chills are subjectively experienced differently across individuals, and the dichotomous distinction between having chills or not may fail to accommodate these differences in recognition or intensity. Therefore, the exploratory use of continuous measurements over typical button press paradigms was preferred, and motivated by the likelihood that chills are not only experienced differently across listeners, but that they can also occur within people at varying intensities (Craig, 2005).

5.3.5 Procedure

Participants were each tested separately and were asked to familiarise themselves with the experiment by reading an information sheet provided (see **Appendix 2** for a procedural outline). Informed consent was obtained through a signature and confirmation that the subject understood the procedure of the experiment. Before the listening experiment began, electrodes were attached to the non-writing hand of participants. Finally, before initiating the main procedure, participants listened to a short excerpt of instrumental guitar music, and were asked to become familiar with the analogue slider for the continuous measurements of chills intensity. In the first block of listening, participants listened to either an original or manipulated version of the three stimuli. After each piece had finished, participants completed the rating scales provided. When ready for the next piece to start, participants could communicate to the investigator in a separate room by using a microphone set up close by. Once participants had listened to the three pieces, they were asked to complete a set of questions, including distractors and others concerning musical preferences and demographics. In the second block of listening, the remaining versions of the three musical stimuli were listened to, following the same procedure as the first block. To conclude the experiment, participants responded to questions regarding musical sophistication, and the frequency of chills experiences in everyday life. Participants were reimbursed £5 for taking part. The experiment lasted approximately one hour, and was approved by the University Ethics Committee.

5.3.6 Data Analysis

All data were processed fully or partially in the R environment, with Bonferroni corrections applied for all multiple comparisons; data that were not independent were analysed with repeated-measures ANOVA tests and linear mixed effects models. Where parametric tests were utilised, residual plots were assessed for any clear deviations from normality or homoscedasticity. For mixed effects models, marginal R^2 was calculated as an indicator of effect size following calculations from Nakagawa and Schielzeth (2013), and this was performed with the *MuMIn* R package (Barton, 2018); for ANOVA tests, partial eta^2 was calculated. For musical sophistication, genre preferences and underlying mechanisms, data were aggregated in accordance with distinct factor structures identified in previous studies (Müllensiefen et al., 2014; Rentfrow & Gosling, 2003).

Skin conductance data display a negative trending behaviour (gradual and linear decrease) over longer periods of time, which was corrected by applying a simple linear model to the data (de-trending). Skin conductance data is also comprised of tonic, baseline biological activity, and phasic event-related activity (Boucsein, 2012), and the two underlying signals need to be separated and identified to accurately analyse physiological patterns. To achieve this, the Ledalab toolbox in Matlab was utilised (Benedek & Kaernbach, 2010). Firstly, all raw data imported into Ledalab were pre-processed, by manually removing artefacts (e.g. sharp peaks from physical movement or biological variation), and by applying a smoothing Butterworth low-pass filter (order = 1, lower cut-off = 5). Next, the continuous decomposition analysis

(CDA; Benedek & Kaernbach, 2010) method was applied to the data, to decompose the raw skin conductance measurements into tonic and phasic signals; this method underwent two optimisation processes that estimate a best fit of the decomposed signal to the original (indicated by tau values), and was performed with the significant peak value set at .001. Following CDA, skin conductance data were normalised and baseline corrected within each participant to control for individual differences in the skin conductance response (Khalfa et al., 2002).

In the current analysis, the phasic skin conductance response (SCR) was a central focus, in terms of average amplitude levels for three regions of interest, namely the '*chills section*' in the piece, three '*control sections*', and the '*removal section*' in the manipulated version of the piece; these regions were also utilised for continuous measurement analysis, with both sets of data log-transformed before comparisons to correct for non-normal data distributions. The chills sections for each piece were the predetermined moments found in the previous survey that elicit chills; the control sections were three shorter moments in the music that did not overlap with the chills sections, serving as a within-piece comparison; finally, the removal sections in the manipulated conditions referred to the same moment in the music where the chills section would have started, but instead was comprised of musical progressions that would have followed the chills section before editing (see **Figure 5.1**), providing a test of direct effects of musical manipulation. For Jupiter, the chills section was 107 seconds in length, compared to a removal section of equal length, and three control sections of 36, 36, and 35 seconds respectively. However, for Glósóli and Ancestral, chills sections were limited to the first 36 seconds, compared to a removal section of equal length, and three control sections of 12 seconds each; this duration limit was a result of manipulated versions of the pieces being too short, such that the piece would not continue beyond the duration of the original chills section, making comparisons between removal sections and full duration chills sections impossible.

To strengthen the analysis, for the control sections, three shorter *musical-control* sections in each piece were first specifically selected to contain notable musical features of their own linked to chills, such as dynamic changes, entrances of new instruments, and repetitions of a theme (Grewe et al., 2007; Panksepp, 1995; Sloboda, 1991). In addition to these musical-control sections, a second set of *acoustic-control* sections were established based on psychoacoustic similarity to the chills section in question; utilising MIR Toolbox (Lartillot, Toiviainen & Eerola, 2008), musical content similarity was calculated by comparing Euclidean distances between the chills section and every other part of the piece using mel-frequency cepstrum coefficients (MFCCs), cepstrum profiles, and spectral content (range 80-3000 Hz), with a window size corresponding to the duration of the chills section. For Glósóli and Ancestral, frame lengths for comparison were 12 seconds, and for Jupiter frames were 35 seconds, with each iteration shifting the section of comparison forward by one second. From these indices of similarity, acoustic-control sections were determined through peak detection in the acoustic similarity values within the piece, focussing on points of peak convergence across the various psychoacoustic measures; peaks were defined as similarity values higher than the previous and successive values by a magnitude of 10 percent (or higher) of the range between maximum and minimum similarity values in the analysis. This chills vs. acoustic-control section comparison thus involved a novel set of three control sections that most resembled the chills sections in psychoacoustic terms.

Further psychoacoustic features of the musical stimuli were identified and analysed with MIR Toolbox, following procedures previously documented by Eerola

(2011). Low-level features included RMS values, brightness and roughness; some other higher-level features were explored such as event density, key clarity and pulse clarity. As reviewed earlier, some of the low-level features such as loudness and roughness have previously been correlated with musical chills (Grewe et al., 2007; Nagel et al., 2008). The high-level features were an exploratory effort to capture changes in textural density (such as the number of onsets within each short segment in event density), tonal changes (key clarity indexes how perceptually well-defined the key is at each moment in time), and how salient the underlying pulse of the music is (pulse clarity). These features were downsampled to the same rate as the continuous ratings and skin conductance recordings (32 Hz), to allow for correlations with SCR and continuous measurement data.

5.3 Results

5.3.1 Frequency of Chills

Across six listening conditions, three original and three manipulated, self-reports of chills experiences were collated, with the distribution assessed through the McNemar's test due to a repeated-measures design; each quadrant of the contingency table addressed whether participants had chills in just the original condition, just the manipulated condition, both conditions, or no conditions. Overall effects of the experimental manipulation on the frequency of chills show a marginally significant difference in distribution of chills depending on listening conditions (x^2 = 3.85, p = .049, Φ = 0.23); this reflects a consistent nominal but non-significant pattern found for each piece, with all original conditions resulting in a higher frequency of chills responses across listeners. For Glósóli, participants reported in total 10 experiences of chills in the original condition, and 7 in the manipulated version (x^2 = 1.00, p = .31, Φ = 0.20); for Jupiter, 10 episodes of chills were reported for the original condition, and 8 for the manipulated version (x^2 = 0.50, p = .47, Φ = 0.14); finally, participants reported 10 experiences of chills in the original version of Ancestral, and 6 in the manipulated condition (x^2 = 1.28, p = .25, Φ = 0.23).

5.3.2 Self-report Data

Emotions

After each piece, participants responded to scales regarding feeling moved and emotional intensity (see **Figure 5.2**). The differences between these measurements were then assessed depending on whether participants had reported chills or not, utilising a one-way MANOVA test with being moved and emotional intensity as two dependent variables, and self-reports of chills experiences (yes/no) as the independent variable. In the original conditions, the presence or absence of chills experiences had a significant effect on being moved and intensity ratings (F [2, 68] = 16.88, p = <.0001, partial eta^2 = .33), with further ANOVA tests confirming the effect for being moved (F [2, 68] = 13.26, p = <.0001, partial eta^2 = .25), and emotional intensity (F [2, 68] = 21.78, p = <.0001, partial eta^2 = .33); further corrected comparisons showed that being moved ratings were significantly higher when chills were experienced in Glósóli (t = -3.25, p = .02, d = 1.34), but not in Jupiter or Ancestral. For emotional intensity, corrected comparisons showed that ratings were significantly higher when chills were experienced in Glósóli (t = -3.80, p = .005, d = 1.57) and Ancestral (t = -3.37, p = .01, d = 1.39), but not for Jupiter. Interestingly, the same one-way MANOVA revealed similar results in the manipulated conditions (F [2, 67] = 5.29, p

= .007, partial eta^2 = .13). To explore whether chills were more moving or intense in the original stimuli, ratings were compared across experiences of chills in original and manipulated conditions; a difference approaching significance between conditions was found for being moved and emotional intensity ratings in chills experiences (F [2, 48] = 2.67, p = .07); notably, chills were rated as more intense in the original conditions (F [2, 48] = 10.22, p = .0004, partial eta^2 = .11), but not more moving.

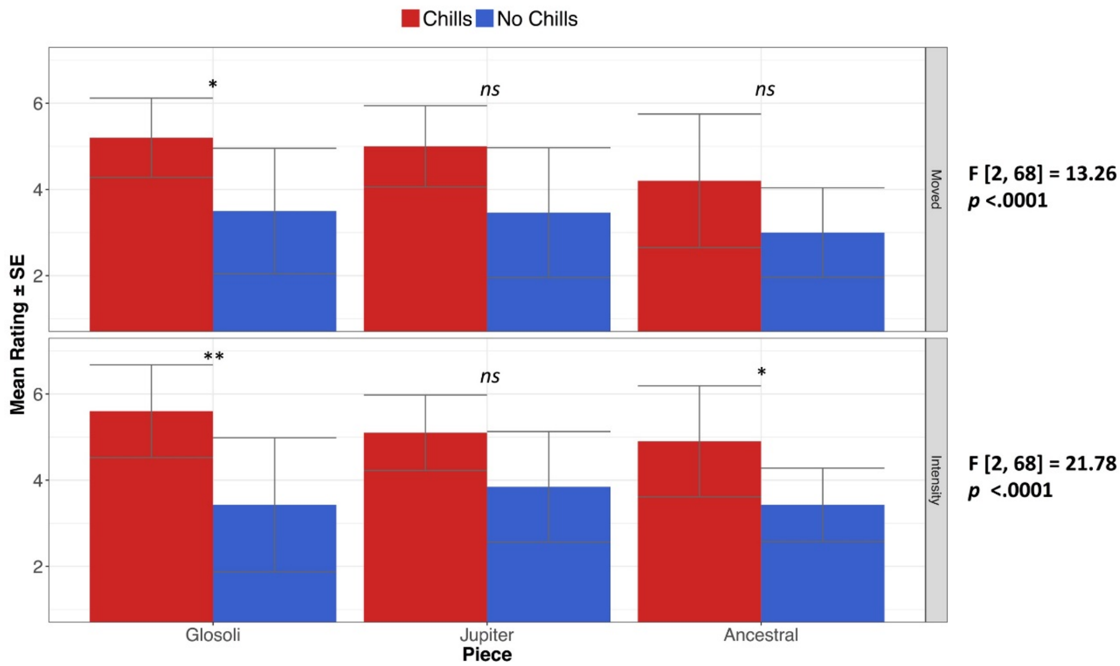

Figure 5.2: Mean ratings of being moved and emotional intensity for original conditions, depending on whether chills were experienced during listening (** = $p < .01$; * = $p < .05$)

Finally, to assess how removing specific chills sections affected more general feelings during listening, emotional descriptors and ratings for underlying mechanisms of musical emotion were also assessed. A total of 11 descriptors were derived from the GEMS model, with Glósóli experiences rated as relaxing, calm and inspiring, Jupiter as happy, energetic and powerful, and Ancestral as sad, tense and powerful; these descriptors suggest that whilst chills are experienced at similar rates across the three pieces, the emotional qualities may vary. No ratings of emotion differed significantly between listening conditions for each piece, suggesting that the overall emotional experience is maintained even after removing chills sections in the music. Similar patterns are also found in ratings of underlying mechanisms: for all pieces, rhythmic entrainment and emotional contagion mechanisms received high scores, and no significant differences were found for any mechanism across original and manipulated conditions.

Musical Preferences, Sophistication, and Familiarity

In terms of musical preferences and chills, some differences were found across the four main factors of the STOMP, labelled *reflective and complex* (M = 4.69, SD = 1.18), *intense and rebellious* (M = 4.68, SD = 1.60), *upbeat and conventional* (M = 4.13, SD = 1.16), and *energetic and rhythmic* (M = 4.00, SD = 1.33). In a one-way MANOVA with the experience of chills (yes/no) as the independent variable and four preference factors as dependent variables, a significant effect was found for Glósóli (F [4, 43] = 3.67, p = .011, partial eta^2 = .25) and Jupiter (F [4, 42] = 2.62, p = .048, partial eta^2 = .19), but not for Ancestral. Further corrected comparisons revealed greater preferences for reflective and complex genres for participants who experienced chills in Glósóli conditions (t = 2.98, p = .018, partial eta^2 = .16), and Jupiter conditions (t = -2.80, p = .029, partial eta^2 = .14), when compared with non-chill responders.

To assess whether participants scoring higher on musical sophistication measures experienced more chills during the experiment (M = 31.12, SD = 8.65, possible range = 7 to 42), listeners were separated into a high chills group (experienced chills at least once in 4 to 6 of the pieces), a low chills group (experienced chills at least once in 1 to 3 of the pieces), and a no chills group; a one-way ANOVA indicated no significant differences for musical sophistication scores as dependent on the number of chills experienced in the experiment (F [2, 18] = 0.78, p = .47).

In terms of familiarity, Jupiter was the most familiar with a mean rating of 3.83 (SD = 1.46), whilst both Glósóli (M = 1.60, SD = 1) and Ancestral (M = 1.50, SD = 0.97) were generally unfamiliar to participants; ratings of familiarity did not differ across chills and non-chills listening experiences. Interestingly, when comparing across original and manipulated versions, a significant difference in familiarity ratings was found for Jupiter (t = 5.77, p <.0001, partial eta^2 = .60), with participants less familiar with the manipulated version.

5.3.3 Skin Conductance

For skin conductance, mean phasic SCR activity levels were analysed across chills sections, musical-control and acoustic-control sections, and removal sections for each piece. Phasic SCR was preferred over tonic activity as it better represents event-related physiological responses (Boucsein, 2012). Due to occasional hardware issues, usable data were not collected from all 24 participants (Glósóli: original N = 19, manipulated N = 21; Jupiter: original N = 20, manipulated N = 21; Ancestral: original N = 21, manipulated N = 20).

The first analysis included musical-control sections, containing structural features previously linked to chills. A mixed-effects linear model was applied to the SCR data using the '*nlme*' package for R (Pinheiro et al., 2017), comparing means across three conditions (chills, musical-control, removal) with a random effect to compensate for participants contributing to data in every condition and piece; this method was chosen over a standard repeated-measures ANOVA because of a higher level of flexibility in planned post-hoc comparisons. Results for Glósóli showed a significant effect of condition on SCR (F [3, 56] = 9.14, p <.0001, R^2 = .25), with planned contrasts showing that SCR in the chills section was significantly higher than musical-control sections (z = 2.81, p = .004), but not statistically different from the removal section (z = -1.52, p = .12). Results from Jupiter also show a significant effect of condition on SCR values (F [3, 58] = 3.65, p = .017, R^2 = .11), with SCR in the chills section significantly higher than the musical-control sections (z = 3.04, p = .002), and nominally, but not significantly, higher than the removal section (z = 1.77, p = .075). Finally, results for Ancestral showed a significant effect of condition on SCR values (F [3, 58] = 5.52, p = .002, R^2 = .16), with SCR higher in the chills section compared to the musical-control sections (z = 3.71, p = .0002), but not with the removal section (z = 0.73, p = .46). A visualisation of these results is presented in **Figure 5.3**.

The same analysis procedure was carried out a second time, but this time with acoustic-control sections selected based on their psychoacoustic similarity to the chills section. The mixed-effects linear model again found significant effects of condition on SCR for all pieces (Glósóli: F [3, 56] = 11.76, p <.0001, R^2 = .30; Jupiter: F [3, 58] = 4.02, p = .011, R^2 = .11; Ancestral: F [3, 58] = 10.45, p <.0001, R^2 = .26), but this time only chills and acoustic-control sections were subject to planned comparisons; these comparisons supported results from the first analysis, with phasic SCR being significantly higher in chills sections when compared to acoustic-control sections, for all pieces (Glósóli: z = 2.99, p = .002; Jupiter: z = 3.31, p = .0009;

Ancestral: $z = 4.55$, $p < .0001$). It is important to note that whilst phasic SCR was the focus, the same analysis was carried out for tonic SCL data with similar results.

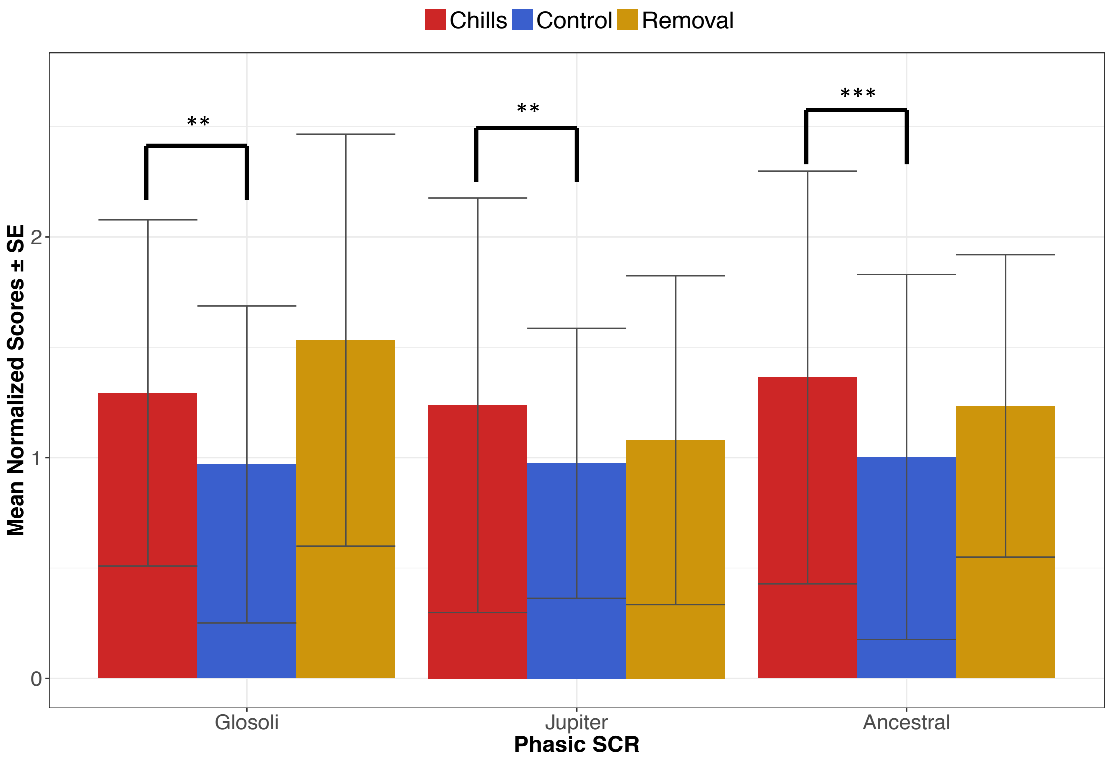

Figure 5.3: Average phasic SCR during chills, musical-control and removal sections within each piece (*** = $p < .001$; ** = $p < .01$); error bars indicate standard error.

5.3.4 Continuous Measurements of Chills Intensity

A further validation of chills was the continuous measurements of chills intensity. The same analysis strategy was carried out as with skin conductance, comparing mean measurements across chills, control and removal sections in each piece; again, the analysis was completed twice, one including musical-control sections derived from musicological considerations, and the other including acoustic-control sections assessed to be comparable to chills sections in psychoacoustic terms. As some participants did not experience chills, usable data were not collected from all participants (Glósóli; N = 20; Jupiter: N = 21; Ancestral: N = 20).

For the first analysis involving musical-control sections, a significant effect of condition on continuous measurements was found for Glósóli (F [3, 57] = 10.79, p <.0001, R^2 = .12), with post-hoc comparisons showing that continuous measurements were significantly higher in the chills section compared to the musical-control section (z = 5.41, p <.0001) and the removal section (z = 4.00, p <.0001). For Jupiter, a significant effect of condition was found (F [3, 60] = 6.34, p <.0001, R^2 = .04); planned contrasts revealed a significant difference between the higher ratings in the chills section and the lower ratings in the musical-control sections (z = 4.18, p <.0001), but no significant difference between chills and removal sections (z = 1.04, p = .29). Finally, results for Ancestral showed a significant effect of condition (F [3, 57] = 10.75, p <.0001, R^2 = .13), with post-hoc comparisons showing that continuous measurements in the chills section were significantly higher than both the musical-control sections (z = 5.52, p <.0001) and the removal section (z = 2.41, p = .015). A visualisation of these results is presented in **Figure 5.4**.

For the second analysis involving acoustic-control sections, the mixed-effects linear model again found significant effects of condition on continuous measurements for all pieces (Glósóli: F [3, 57] = 26.90, p <.0001, R^2 = .22; Jupiter: F [3, 60] = 4.72, p = .005, R^2 = .03; Ancestral: F [3, 57] = 23.57, p <.0001, R^2 = .29). In comparing chills and acoustic-control sections, results showed that continuous measurements were significantly higher in chills sections for all pieces (Glósóli: z = 8.14, p <.0001; Jupiter: z = 3.64, p = .0002; Ancestral: z = 7.24, p <.0001).

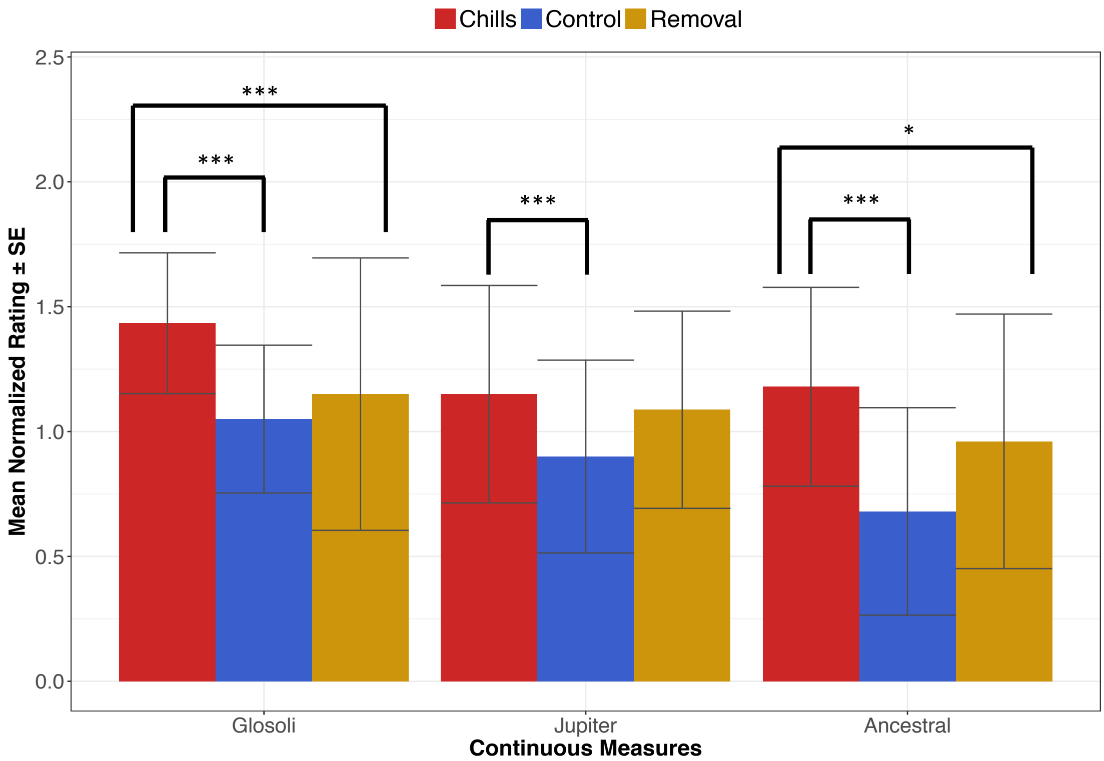

Figure 5.4: Mean continuous measurement ratings, comparing chills, musical-control and removal sections for each piece (*** = p <.001; * = p <.05); error bars indicate standard error.

5.3.5 Monte Carlo Simulation Approach

To eliminate any notion that the section comparisons reflect convenient points for analysis, and to further corroborate and support the results regarding skin conductance and continuous measurements across chills and control sections in the three pieces, a Monte Carlo Simulation process was utilized, with mixed-effects linear models fitted 10,000 times for each original piece; each iteration of the model would compare mean values of phasic SCR and continuous measurements across a randomly selected 5 second epoch extracted from the chills section, with a randomly selected epoch of equal duration from any moment in the piece (including the chills section). For every model, confidence intervals were extracted, with values averaged over 10,000 iterations. This approach was applied only to original versions of the stimuli to support control section selections, and validate the general emotional efficacy of chills sections. Results of multiple comparisons with phasic SCR showed that for Glósóli, average 95 percent confidence intervals for the mean differences between control and chills selections were -0.30 and -0.24; results were similar for Jupiter (mean 95 percent CI = -0.21, -0.15) and Ancestral (mean 95 percent CI = -0.37, -0.31). With regards to continuous self-reports of chills intensity, results were replicated for Glósóli (mean 95 percent CI = -0.69, -0.61), Jupiter (mean 95 percent CI = -0.73, -0.66), and Ancestral (mean 95 percent CI = -0.79, -0.73), indicating that the chills section appeared to be more emotionally salient than most other moments in the music. A visualization of these simulations can be found in **Figure 5.5**.

5.3.6 Psychoacoustic parameters

As a final exploratory process, psychoacoustic parameters were correlated with both phasic SCR and continuous measurements to assess whether some features may be linked to the experience of chills in listeners; given the size of datasets in the correlation computations, and the fact that observations were not independent, statistical significance was ignored, with an emphasis placed on the strength of relationships. The Pearson correlation results (see **Table 5.1**) suggest that for Glósóli and Ancestral there are strong positive relationships between continuous measurements of chills intensity and numerous features, namely RMS, brightness, and roughness. Interestingly, for Jupiter, correlations are less consistent and weaker. Furthermore, there appear to be no clear correlations between any psychoacoustic features and phasic skin conductance changes, with some features displaying negative correlations. To account for possible lag between psychoacoustic features and changes in continuous measurements or phasic SCR, cross-correlation analysis was also carried out, which confirmed that the potential lag structure between stimulus qualities and participant responses did not affect the correlation results.

Table 5.1: Pearson correlations between psychoacoustic parameters and both phasic SCR and continuous measures of chills intensity.

	Continuous Measures			*SCR*		
Feature	**Glósóli**	**Jupiter**	**Ancestral**	**Glósóli**	**Jupiter**	**Ancestral**
RMS	.47	.56	.78	-.49	.06	.20
Brightness	.62	.13	.49	-.09	-.28	-.02
Centroid	.70	.23	.61	-.17	-.22	.14
Entropy	.52	.18	.39	-.30	-.37	.03
Roughness	.80	.42	.76	-.26	.03	.17
Flux	.68	.50	.77	-.40	.01	.10
Novelty	.14	-.04	.10	.11	-.15	-.10
Event Density	.31	.41	.73	-.38	.05	.17
Key Clarity	.29	.21	.25	.01	-.39	.04
Pulse Clarity	.59	-.08	.01	-.24	-.22	-.08

5.4 Discussion

This second study of the current dissertation provided the first causal investigation into the experience of musical chills, by manipulating musical stimuli and testing effects on the response in an empirical setting; the experiment presents an important step in moving beyond the existing limitations of strictly correlative approaches. By removing previously identified chills sections in three pieces of music reported across the survey presented in the previous chapter, the frequency of chills was consistently reduced across listeners and pieces; continuous measurements of chills intensity often decreased significantly, with a similar but less consistent pattern observed for phasic skin conductance activity. It is worth noting that the overall emotional experience during each piece did not significantly change when chills sections were removed, nor were there any clear links between listening conditions and proposed underlying mechanisms of music and emotion (Juslin, 2013), although all three pieces scored highly on rhythmic entrainment and emotional contagion mechanisms; this finding is comparable to mechanism ratings reported in **Chapter 4**. However, chills experiences were seemingly more intense on average when elicited by original versions of the stimuli, compared to manipulated versions.

Chills were characterised as an intense and moving response in the experiment when compared to non-chill experiences, although this was largely driven by experiences with Glósóli and Ancestral. Interestingly, both continuous measurements of chills intensity and phasic skin conductance levels generally supported the frequency of chills between conditions, and the emotional salience of chills sections. There were some exceptions and inconsistencies however, particularly with the Jupiter listening conditions, which may be a result of familiarity effects and extra-musical factors such as episodic memory or evaluative conditioning mechanisms (Juslin & Västfjäll, 2008).

The results of continuous measurements of chills intensity were clear across Glósóli and Ancestral, indicating that chills sections were emotionally intense compared to musical-control or acoustic-control sections, and removal sections.

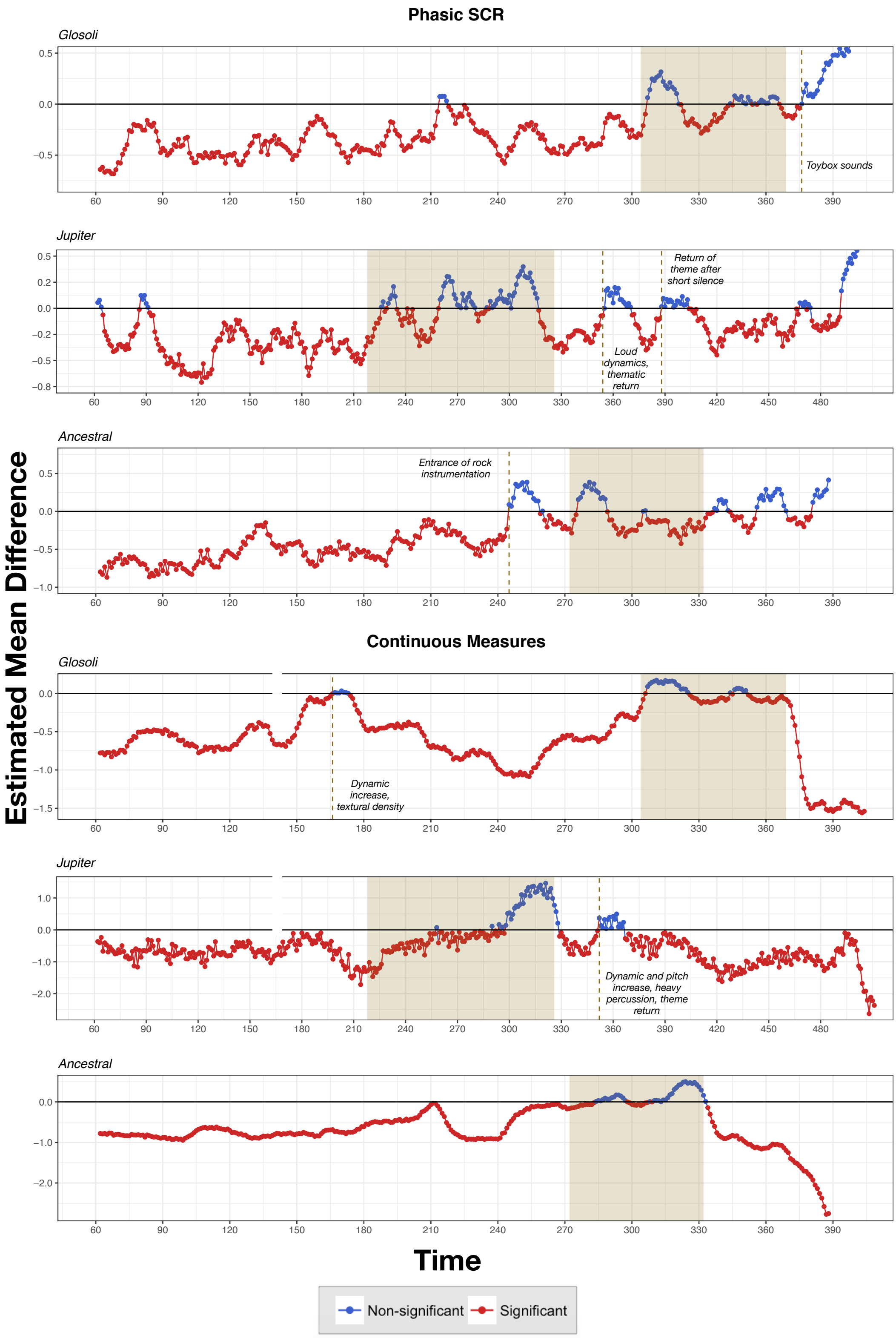

Figure 5.5: Estimated mean differences from the monte carlo simulations, comparing random 5s control sections from any point in the piece, to random 5s sections from within the shaded chills section. Dashed lines indicate notable structural moments in music linked to non-significant differences. Data points are visualised as significant when the estimated mean difference was below zero.

These findings were less clear for phasic skin conductance; whilst skin conductance was normally significantly higher in chills sections compared with musical-control or acoustic-control sections, this was rarely the case when compared with removal sections. This may firstly be a result of musical qualities in the removal section; for example, the removal section in Glósóli contained a texture and instrument distinct from most of the piece, namely a glockenspiel and 'toy box' sound; this sound was often reported as a favourite moment by listeners in the experiment. An interest point is that this type of sound has been linked to cuteness, albeit in unpublished work (see Huron, 2015), and in fact the perception of cuteness has recently been associated with experiences of being moved (Stiennes, Blomster, Seibt, Zickfeld & Fiske, 2019); this may explain why the removal section in Glósóli continued to elicit increases of psychophysiological arousal. The Ancestral removal section introduced for the first time a female voice, revisiting lyrics from earlier in the piece, although few participants mentioned this aspect when discussing favourite moments. However, these explanations linked to musical features struggle when considering the continuous measurement results, showing significantly higher ratings in chills sections compared to removal sections. A secondary explanation may be related to the experimental design. Some participants heard the original versions of the music first; consequently, when they listen to the same piece again, and are expecting the chills section, some form of veridical expectancy violation may occur when it is removed, referring to explicit expectations formed when one has heard the music before, or is very familiar with the music (Guo & Koelsch, 2016; Huron & Margulis, 2010). This may have confounding effects on physiological markers of emotional arousal such as skin conductance, and may also result in lower continuous ratings if the listener was anticipating a standout or preferred section in the music, only to be disappointed when it is removed. However, this can operate in an opposing fashion, such that skin conductance results are exaggerated when participants do not explicitly expect the chills section following initial exposure to the manipulated versions of the stimuli. Every stimulus presentation order was pseudo-randomised and individualised to control for these confounding issues, although small effects may not be fully ruled out. A final explanation may simply be due to the wide variability across individuals with regards to skin conductance (Khalfa et al., 2002); some listeners may be physiologically sensitive and hyper-responsive, whereas some may not respond in any way; there may also be habituation effects across time in skin conductance, such that stimulus presentation order may influence this measurement, more so than continuous measurements. Again however, the pseudo-random presentation orders can control for habituation effects; furthermore, skin conductance measures were normalised within each participant, and mixed-effects linear models incorporate and account for individual differences in reactivity when fitted to the data, so individual sensitivity differences were mostly captured.

Perhaps a more interesting explanation underlying the negligible difference between chills and removal sections in phasic skin conductance is derived from understanding the impact of local, preceding musical contexts. This is a particularly striking idea given that although the chills section in Glósóli was characterised by a change in dynamics, texture and energy (Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991), and the chills section in Ancestral might be described as the entrance of a new leading instrument and a clear solo and accompaniment relationship (Grewe et al., 2007; Guhn et al., 2007), similar features are also encapsulated in various control sections in these pieces, without resulting in any emotional response like those identified in the chills sections. Ancestral provides a notable example, as each musical-control section, derived from musicological considerations, can be conceptualised either as an entrance of a voice with English lyrics, entrance of a cello over minimal accompaniment, or a pronounced, sudden dynamic and textural change, all of which are features linked to chills in previous work; despite this, the guitar solo remained the most effective elicitor of chills and emotionally intense experiences. This suggests an important role of local musical contexts on the chills potency and emotional salience of musical features within a piece, and this role may be reflected in a relatively small effect of stimulus manipulation on the frequency of chills in the current experiment. This effect of context in musical chills has been alluded to by Panksepp (1995), suggesting that *'…it is unlikely that such periods of emotional intensification could have a sufficiently powerful effect to produce chills were it not for the background mood of nostalgic sadness established by the rest of the piece.*' (p. 193). This should not come as a surprise; a sudden increase in dynamics is only made sudden by preceding musical developments. It may be then, especially when referring to the physiological data, that the moments preceding the onset of the chills sections are also central to the experience and results; regardless of whether listeners heard the chills or removal section, the musical build up to the onset of these epochs may have been an important driver of physiological activity. These considerations align with findings from Salimpoor et al. (2011), noting a distinction in brain activity between anticipatory and experiential phases of the chills response; the notion of a 'pre-chill' has also been echoed by Wassiliwizky et al. (2017b), and in the current context implicates mechanisms of musical expectancy (Huron, 2006; Juslin & Västfjäll, 2008). The relative impact of local musical contexts on the effects of specific musical features or moments linked to chills, currently and in previous literature, appears to be an essential target for future research, and may contribute to ongoing theories of musical tension, release and expectation (Lehne & Koelsch, 2015). However, without attempting to progress from correlative work into causal manipulations of the elusive musical chills response, these interactions and effects cannot be determined.

Even if we consider the possible effects of musical context on the likelihood of musical features eliciting chills, for what reasons do these features induce chills under any circumstances? Research has utilised chills to indicate pleasurable, high arousal emotional states (Blood & Zatorre, 2001; Rickard, 2004; Salimpoor et al., 2011; Salimpoor et al., 2009), and in other studies chills have repeatedly been linked to aspects of musical expectation, such as sudden dynamic changes (Grewe et al., 2007; Panksepp, 1995) and unprepared harmonies (Sloboda, 1991), with the vigilance theory of musical chills encapsulating these findings (Huron, 2006). A contrasting perspective contextualises chills in terms of social bonding (Panksepp 1995; Panksepp & Bernatzky, 2002), indicated by the mixed state of being moved (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2015), and elicited through intensified communal sharing relations (Fiske et al., 2017). In **Chapter 3**, and considering findings from **Chapter 4**, it was suggested that due to the variety of psychophysiological and emotional experiences reported during musical chills, and the large corpus of music that elicits the response, the concept of chills may encapsulate several distinct phenomenological experiences that might be defined by the causal underlying mechanisms being activated, such as expectancy violations, fear, awe, or social bonding and empathy. The current empirical manipulation of musical chills suggests a similar idea: Firstly, emotional experiences with each of the three pieces were characterised by different descriptors, such as happiness and energy for Jupiter, and sadness and tension for Ancestral; secondly, the chills sections across the three pieces appeared to be emotionally salient and linked to chills, resulted in comparable effects when removed, yet shared few structural similarities with each other. It is possible that these chills sections are engaging with different listening processes or mechanisms (i.e. brain stem reflexes, contagion, empathy, rhythmic entrainment, or musical expectancy), that share common physiological outcomes (i.e. goosebumps, shivers or tingling), but differ in terms of emotional and aesthetic experience. If this is indeed the case, an important question for underlying mechanisms of music and emotion would be how specific musical features activate differing mechanisms and result in a multitude of emotional experiences, depending on the local musical structure and the context in which they are embedded. It is worth noting that without further systematic investigation this remains conjecture, and it is important to keep in mind what the individual listener and listening context may contribute to the experience.

In terms of psychoacoustic parameters, results show that increases in loudness, brightness and roughness were correlated with increases in continuous measurements of chills intensity in both Glósóli and Ancestral, although few correlations were found with phasic skin conductance. These findings offer some support to previous studies (Grewe et al., 2007; Nagel et al., 2008), although currently it is not clear as to how these features are linked to chills. Perhaps loudness and acoustic intensity engages a vigilance or fear response, given that loud sounds normally signify important events; more gradual increases in loudness, such as that in Glósóli, may also allude to the auditory looming phenomenon, and the perception of something approaching oneself (Ghazanfar et al., 2002). Further to this, roughness, linked to dissonance and the critical bandwidths of auditory processing (Plomp & Levelt, 1965), may be associated with threatening sounds, perhaps from predators, that may elicit vigilance chills or gooseflesh (Arnal et al., 2015). From a different angle, brightness and higher frequency energy may be a common psychoacoustic attribute across distress vocalisations and music, that which (Panksepp, 1995) has suggested can result in chills through social bonding processes; interestingly, higher pitch has been associated with increased ratings of coldness over warmness in an investigation of audio-tactile metaphors (Eitan & Rothschild, 2011). Brightness may also be linked to auditory looming, especially in cases of gradual increases; as higher frequency sound waves do not travel as far as lower frequencies, increased proportions of higher frequency energy may indicate closer perceived proximity between listener and sound source. As it stands, given the lack of research on chills and psychoacoustic parameters, the explanations above are necessarily speculative, but remain promising avenues for further nuanced developments of the current causal manipulation paradigm for musical chills experiences.

Jupiter yielded more inconsistent results compared with the other two pieces in the current experiment, with a more balanced frequency distribution of chills between original and manipulated conditions, slightly less consistent effects of manipulation on continuous measurements, and fewer correlations found with psychoacoustic features. One immediate explanation for these results is that of the three pieces, Jupiter was by far the most familiar to listeners, which introduces a higher possibility of extra-musical effects that could not be controlled, such as the emotional impact of episodic memories (Belfi, Karlan & Tranel, 2016; Janata, 2009; Janata et al., 2007), or various conditioning effects (Blair & Shimp, 1992; Walther et al., 2005). Familiarity is an important variable to consider, although effects with regards to musical chills are currently inconsistent and unclear (Benedek & Kaernbach 2011; Panksepp, 1995; Rickard, 2004). A second possibility is that given the longer duration of Jupiter in comparison to other stimuli, and the frequent changes occurring throughout the piece, there is simply more time and scope for the chills response outside of any specific section of music, resulting in a smaller effect when this chills section is removed. It must be noted however that when participants were asked to describe the favourite moment of the piece, many reported exactly the chills section in question, referring to the lyrical adaptation of the theme ('I Vow Thee to My Country'), or the moment when chaotic orchestral movements were calmed by the new string elements and theme. Intriguingly, by removing the chills section, ratings of familiarity were significantly decreased, suggesting that Jupiter could be an interesting candidate for a specific musical progression that is particularly well-known, embedded in a piece that is generally less familiar; such an example may serve as a stimulus for manipulating effects of extra-musical mechanisms on the emotional experience of listeners.

Limitations

There are limitations to this second study worth highlighting. Firstly, the continuous measurements of chills intensity were used as an exploratory method for capturing the nuances and contours of chills experiences that are unlikely to be as simple as experiencing chills or not. However, behavioural data suggest that some listeners used continuous measurements as indicators of general emotional intensity instead; although there is little known about individual thresholds of recognizing chills experiences, some continuous data consistently reflected some form of response, and it is unlikely that these listeners were experiencing chills throughout the course of the piece. Furthermore, concurrent tasks during music listening may affect the affective experience (Jäncke et al., 2018; Markovic, Kühnis & Jäncke, 2017), although there are some inconsistent results (Hutcherson et al., 2005). Regardless, the continuous measurement task was highly simplified, and whilst some emotional intensity may have been lost, the stimuli remained effective elicitors of chills, and the current results and effects of manipulation were clear. Secondly, as with most chills studies there is a verification problem; although some progress has been made utilising skin conductance measurements, the response is still only an indicator of general changes in emotional arousal, and despite the use of self-reports, skin conductance and continuous measurements, the chills response has still not been fully confirmed. For future empirical investigations, it is central to assess how chills might better be verified without limiting the possibility of capturing the response in lab settings (see Benedek & Kaernbach, 2011). Thirdly, the sample size for this experiment was quite small; however, it seems unlikely that increasing the size of the sample would affect the overall outcomes of this study, and in fact to find robust differences in physiological response and continuous measurements of chills intensity in the current sample is noteworthy. In addition, the current sample size is comparable to various studies investigating musical chills (Egermann et al., 2011; Guhn et al., 2007; Nagel et al., 2008; Rickard, 2004). Fourthly, as the manipulation procedure resulted in duration differences between original and manipulated versions of the stimuli, there may be confounding effects of attention or fatigue in the longer versions; however, this was largely accommodated again through stimulus presentation orders, minimal duration differences, and detrending data to deal with longer-term trends resulting from factors such as fatigue. Finally, the current musical manipulations were rather broad, working with larger epochs and sections in music, limiting control over the musical stimuli; however, this was a necessary decision given that manipulations of the chills response are rarely, if ever, investigated in lab settings, and future research should develop on current exploratory findings to target more specific musical or psychoacoustics features in pieces of music. From this perspective, this listening experiment also serves as an effective proof of concept, such that whilst musical chills experiences are rare and difficult to elicit in laboratory settings, they can be manipulated and tested causally.

5.5 Summary

In concluding the second study, this listening experiment demonstrates for the first time the manipulation and suppression of musical chills through changes to various musical stimuli. Results generally converge, showing that predefined chills sections in each piece are judged as emotionally salient and chill-inducing, evidenced through increases in skin conductance, continuous measurements and higher frequency of chills reports in original conditions for all pieces. The chills sections across the three pieces shared few commonalities, and broader emotional experiences with the three pieces were characterised differently, suggesting that musical chills may be elicited through various listening processes and mechanisms, with each contributing to different emotional experiences that share physiological indices; moreover, the chills sections manipulated in this experiment may be characterised in theoretical contexts of both vigilance and social bonding. Furthermore, similar musical features located in other moments of the musical stimuli did not have any comparable effects on emotional experience and chills, suggesting an importance of local, preceding musical contexts that should be systematically investigated in the future. Some important next steps in musical chills research include developing a more detailed, nuanced manipulation procedure, potentially working with psychoacoustic features such as acoustic intensity, brightness and roughness; understanding the possible differentiation of chills experiences and their links to varying musical features; and carrying out comparisons of musical chills with other aesthetic chills responses that occur with films, images and literature, to better understand the variety of aesthetic experiences that are encapsulated by the chills phenomenon.

6. A Vigilance Explanation of Musical Chills? Effects of Loudness and Brightness Manipulations

6.1 Overview of the Study

As discussed extensively across the previous three chapters of the dissertation, no theory of musical chills has ever been explicitly tested; this is particularly important when considering the multiple, possible mechanisms that may underlie associations between chills and sudden dynamic changes (Grewe et al., 2007), crescendos (Panksepp, 1995) and new or unprepared harmonies (Sloboda, 1991). Crucially, by developing a proof of concept method for causally manipulating musical chills in the previous chapter, foundations have been established that allow for further developments and refinements of the manipulation procedure. Additionally, with this iterative refinement, there is the opportunity to explicitly test, for the first time, a theory of chills. This is the central aim of the current chapter, with a focus on vigilance theory, given that this account accommodates most of the extant correlational literature on musical chills.

In an earlier, original formulation provided by Huron (2006), it was suggested that syntactical expectancy violations in music could elicit a rough, unconscious fear and vigilance response, because of the maladaptive outcome of incorrect prediction; from here, the threat signalling functionality of goosebumps may be engaged. However, whilst causally manipulating musical chills, as documented in the previous chapter, is a substantial step forward for research, it remains methodologically difficult to take real musical excerpts and manipulate musical structures to elicit syntactical violations of some kind; the ecological validity of any such procedure would further be subject to scrutiny. However, the vigilance theory can be intuitively extended beyond musical syntax and expectations, to other musical structures or lower-level features that might be predisposed to eliciting an evolutionary vigilance response; therefore, various psychoacoustic features in music may be a more appropriate starting point for empirically testing the vigilance theory. Previous research is sparse with regards to chills and psychoacoustics, although there are some notable findings linking chills to loudness (Grewe et al., 2007) and auditory roughness (Nagel et al., 2008). Negative chills were further linked to frequencies between 2000 and 3000 Hz (Halpern et al., 1986); interestingly, whilst this frequency band is one in which the human ear is particularly sensitive (Fletcher & Munson, 1933), it is also within the common frequency range of above 2000 or 3000 Hz used as a threshold of spectral brightness calculations (Juslin, 2000; Laukka, Juslin & Bresin, 2005; Lartillot et al., 2008). Alongside loudness, brightness was a further psychoacoustic feature correlated with continuous chills ratings in two of the three pieces assessed in the previous chapter. These two lower-level features are susceptible to experimental manipulations, such as gradually increasing or decreasing loudness or brightness during a section of music linked to chills. These gradual changes may tap into auditory looming mechanisms, a possible process implicated in the vigilance theory of chills (Ghazanfar et al., 2002; Neuhoff, 1998; 2001), and discussed in **Chapter 3**.

Whilst the correlation between loudness and musical chills may be intuitively explained by auditory looming, in contrast to brain stem reflexes and musical expectancy (Juslin & Västfjäll, 2008), there is less evidence outside of music for a similar role of brightness. However, this psychoacoustic feature may also be linked to auditory looming; as higher frequency sound waves do not travel physically as far as those of lower frequencies, it may be that as brightness gradually increases, the sound source is perceived as approaching, with higher frequency sounds becoming more dominant. However, this is conjecture given the lack of research on this psychoacoustic feature in broader auditory looming research; perhaps the correlation between brightness and musical chills requires an alternative explanation.

Considering the recent developments in musical chills research, and theoretical underpinnings linking the response to psychoacoustic qualities in music, the current study aimed to carry out a novel, causal investigation into musical chills, and further the current theoretical understanding of the phenomenon. Given the link between loudness changes, auditory looming and musical chills, the current study aimed to provide the first explicit test of the vigilance theory of chills; this would also be the first causal test of any theory of musical chills. However, brightness was also targeted as an exploratory factor correlated with chills in the previous chapter, a parameter that might also be linked to vigilance processes.

6.2 Methods

6.2.1 Design

A listening experiment was carried out using a short excerpt from two pieces of music used in the previous chapter, shown to be unfamiliar to participants, and effective at eliciting chills. For each excerpt, there were five listening conditions (10 in total), corresponding to one original version and four manipulated versions: increased or decreased loudness, and increased or decreased brightness. To create the manipulated excerpts, the stimuli were edited in terms of overall volume levels or frequency spectrum, using the Logic Pro software. For both pieces, a specific epoch of eight seconds was targeted for manipulation, characterised as the moment of salient structural change linked to musical chills; this included either a sudden dynamic and textural change, or the entrance of a guitar solo. During these epochs, loudness or brightness was gradually increased or decreased, in line with auditory looming processes (see **Figure 6.1;** see **Figure 6.2** for an example time-series of loudness and brightness values across corresponding manipulations). For loudness, the overall volume of the excerpts was increased or decreased by 6dBA; For brightness, frequencies above the common 2000Hz brightness threshold were amplified or reduced by 6dBA (Juslin, 2000; Laukka et al., 2005; Lartillot et al., 2008), manipulating the high-to-low frequency ratio. To control for possible interactions between loudness and brightness, measures were taken to ensure that loudness manipulations did not significantly alter brightness levels, and vice-versa; this was achieved by manually moderating both loudness and brightness in the manipulation procedure, and quantifying the acoustic properties using MIRToolbox (Lartillot et al., 2008), to verify that the manipulation of one parameter did not significantly alter the other. To further validate the manipulations, a short pilot-test was carried out before the main experiment to assess whether the pieces remained realistic, and that listeners ($N = 10$) could hear the manipulations; all manipulations were judged to be reasonably realistic, and were noticeable, delivering the appropriate experiential balance for the experiment. Finally, a feature-extraction procedure was carried out following the methods of Eerola (2011), to assess other descriptive relationships across psychoacoustic parameters and manipulations (see **Table 6.1**); RMS levels were associated with spectral roughness and flux, whilst brightness was linked to the spectral centroid and entropy. This confirmed that loudness and brightness manipulations targeted separate psychoacoustic constructs.

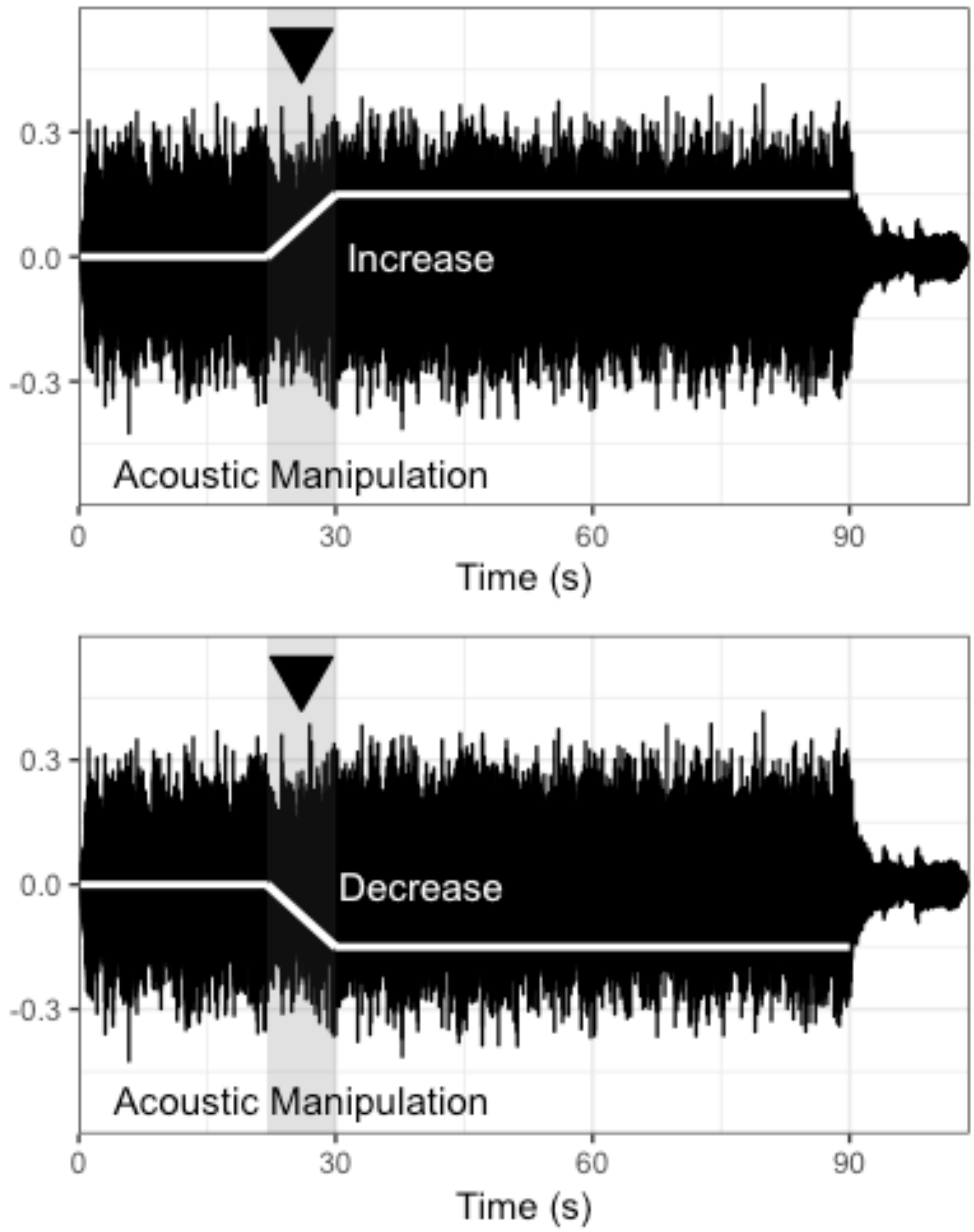

Figure 6.1: Visualisation of the psychoacoustic manipulations procedure; loudness or brightness was gradually increased or decreased over an eight second epoch containing the main structural change and transition in the excerpts.

The central dependent variables for the experiment were the frequency of chills reports, average duration of chills reports, and skin conductance amplitudes during chills reports. Subjective ratings were also collected following each excerpt, regarding the overall listening experience. The experiment followed a within-subjects design, with participants split into two experiment groups, each experiencing five of the 10 listening conditions; these represented a control, high or low loudness, and high or low brightness condition. In each group, participants heard two versions of one excerpt and three of another in a pseudo-randomised order defined by two criteria: 1) the same excerpt could not be heard twice in succession, and 2) versions manipulating the same psychoacoustic parameter could not be heard twice in succession. This was implemented to address effects of fatigue, order effects and habituation in responses resulting from the within-subjects design.

6.2.2 Participants

All participants were recruited through a pre-screening process, which involved a question confirming that participants had experienced chills with music previously (yes/no). A total of 40 participants took part in the experiment. Of the sample, 24 were female, and the mean age was 28.51 (SD = 8.36, range = 19 – 52). An *a priori* power calculation for the experiment was difficult, given the lack of effect sizes corresponding to psychoacoustic manipulations in a musical chills paradigm; as a result, the target and resultant sample size was derived from corresponding samples in previous correlational work on the topic (Blood & Zatorre, 2001, N = 10; Craig, 2005, N = 32; Egermann et al., 2011, N = 14; Grewe et al., 2007, N = 38; Rickard, 2004, N = 21; Salimpoor et al., 2009, N = 32; Salimpoor et al., 2011, N = 10). However, standardised effect sizes are reported in the current experiment to aid power calculations for future research on chills. For the descriptive statistics of the sample, see **Appendix 3**.

Table 6.1: Mean *z*-values for six psychoacoustic parameters across stimulus conditions. Bolded values indicate related parameters.

	RMS	Brightness	Centroid	Entropy	Roughness	Flatness
Glósóli						
Control	-.13	.00	-.02	.001	-.20	-.11
High Loudness	**.98**	.00	-.02	.001	**1.04**	**.82**
Low Loudness	**-.65**	-.04	-.04	-.009	**-.52**	**-.55**
High Brightness	-.13	**.19**	**.47**	**.06**	-.05	-.08
Low Brightness	-.05	**-.16**	**-.38**	**-.06**	-.26	-.07
Ancestral						
Control	-.11	-.004	-.03	.004	-.22	-.11
High Loudness	**1.07**	-.004	-.03	.004	**1.19**	**1.05**
Low Loudness	**-.68**	-.007	-.03	-.003	**-.58**	**-.67**
High Brightness	-.14	**.55**	**.68**	**.07**	-.11	-.09
Low Brightness	-.12	**-.54**	**-.58**	**-.08**	-.26	-.16

6.2.3 Materials and Measures

Self-Reports

For every stimulus that participants listened to, a series of rating scales were completed. After each piece had concluded, participants were asked to confirm how familiar they were with the music (Likert 1-5), rate their emotional experience (Likert 1-7; descriptors included *affection, agitated, energy, enjoyment, joy, moved, nervous, nostalgia, sad, sentimental,* and *tender*), and to report any specific bodily activity (yes/no; descriptors included *cold, warm, lump in the throat, tears, smiling,* and *frowning*). The emotional descriptors were derived from the Geneva Emotional Music Scale (Zentner et al., 2008), whilst bodily activity descriptors were derived from previous literature on chills (Algoe & Haidt, 2009; Fiske et al., 2017; Maruskin et al., 2012; Wassiliwizky et al., 2017a). After participants had listened to the first two excerpts in the experiment, they completed the Behavioural Activation/Inhibition Scales (BIS/BAS; Carver & White, 1994). These scales reflect two proposed, general motivational systems underlying human behaviour: *Approach*, referring to a propensity to maintain contact or move closer to a desirable stimulus or event; and *avoidance*, describing the tendency to separate or move further away from undesirable stimuli or events. These motivational dimensions were assessed for three reasons: Firstly, reward seeking has previously been linked to more intense chills experiences and reported frequency of chills (Mori & Iwanaga, 2015), but requires replication; secondly, the approach and avoidance distinction has been utilised to categorise two kinds of chills experiences, namely *goosetingles* and *coldshivers* respectively (Maruskin et al., 2012); finally, whilst it is difficult to assess tendencies to react strongly with attention and vigilance to external events and stimulation, it has been suggested that behavioural inhibition may be associated with experiencing fear, harm-avoidance or anxiety more readily (Carver & White, 1994; Jorm et al., 1998), an individual difference that might predict susceptibility to auditory looming in music, and in turn, chills. As a final ancillary measure, trait empathy data were collected before participants listened to the final stimulus, using the Interpersonal-Reactivity Index (IRI, Davis, 1983); this was motivated by the finding that chills indicate states of being moved (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2015), an experience that may be mediated by empathy in some musical engagements (Eerola et al., 2016).

Stimuli

For the current experiment, an *experimental* excerpt and *control* excerpt were selected based on their unfamiliarity, and efficacy to elicit chills in participants from the previous chapter; this qualitative distinction between experimental and control excerpts in the current context was employed based on whether the underlying musical structure of the excerpts was intuitively linked to auditory looming or not.

The *experimental* stimulus was *Glósóli* by Sigur Rós. An excerpt was extracted from the full piece, lasting 155 seconds and containing a dynamic and textural crescendo, resulting in a sudden increase in dynamics and instrumental layering at the climax; this was mostly the 'chills section' of the piece removed in the previous experiment. This excerpt was chosen as an experimental stimulus as the crescendo and underlying structure was suited to engage auditory looming processes prior to psychoacoustic manipulations; manipulations of loudness, and possibly brightness, were hypothesised to directly emphasise or diminish this capacity of the music.

In contrast, the *control* stimulus selected was *Ancestral* by Steven Wilson. The excerpt taken from this piece lasted 104 seconds, and was characterised by the entrance of a virtuosic guitar solo overlaying a traditional hard rock instrumentation; this excerpt also had minimal lyrical content. Like Glósóli, this excerpt from Ancestral was the 'chills section' manipulated in the previous chapter. Ancestral was designated as a control stimulus because the underlying musical structure (guitar solo) did not have an intuitive capacity to elicit auditory looming experiences; therefore, the excerpt served as a control comparison to assess whether psychoacoustic manipulation effects can be generalised with regards to chills, or are sensitive to interactions with the underlying musical structure.

Importantly, rating scales in the current experiment further confirmed that participants were again reasonably unfamiliar overall with the stimuli (Glósóli mean = 1.90, Ancestral mean = 1.75, possible range: 1 - 5).

Chills Measurement

To capture experiences of musical chills whilst listening, participants reported the onset of a perceived chills experience by pushing down a button (the space bar on the experiment laptop). Additionally, participants could estimate the duration of the chills experience by releasing the button to report the offset of the response, although participants were notified that should this further task detract from the emotional experience, they should focus on the onsets of chills; this precaution was taken to keep the task simple, as performing tasks whilst listening to music may influence emotional and psychophysiological data recorded (Jäncke, et al., 2018). To further validate the chills reports, skin conductance data were collected from participants, for the same reasons as those stated in **Chapter 5**. In the current paradigm, if a button press was not accompanied by significant increases in skin conductance levels, the report was omitted from the analysis. Skin conductance data were collected using two electrodes (Ag/AgCL), attached to the distal phalanx of the index and middle fingers of the non-dominant hand with the NeXus-10 MKII and BioTrace software.

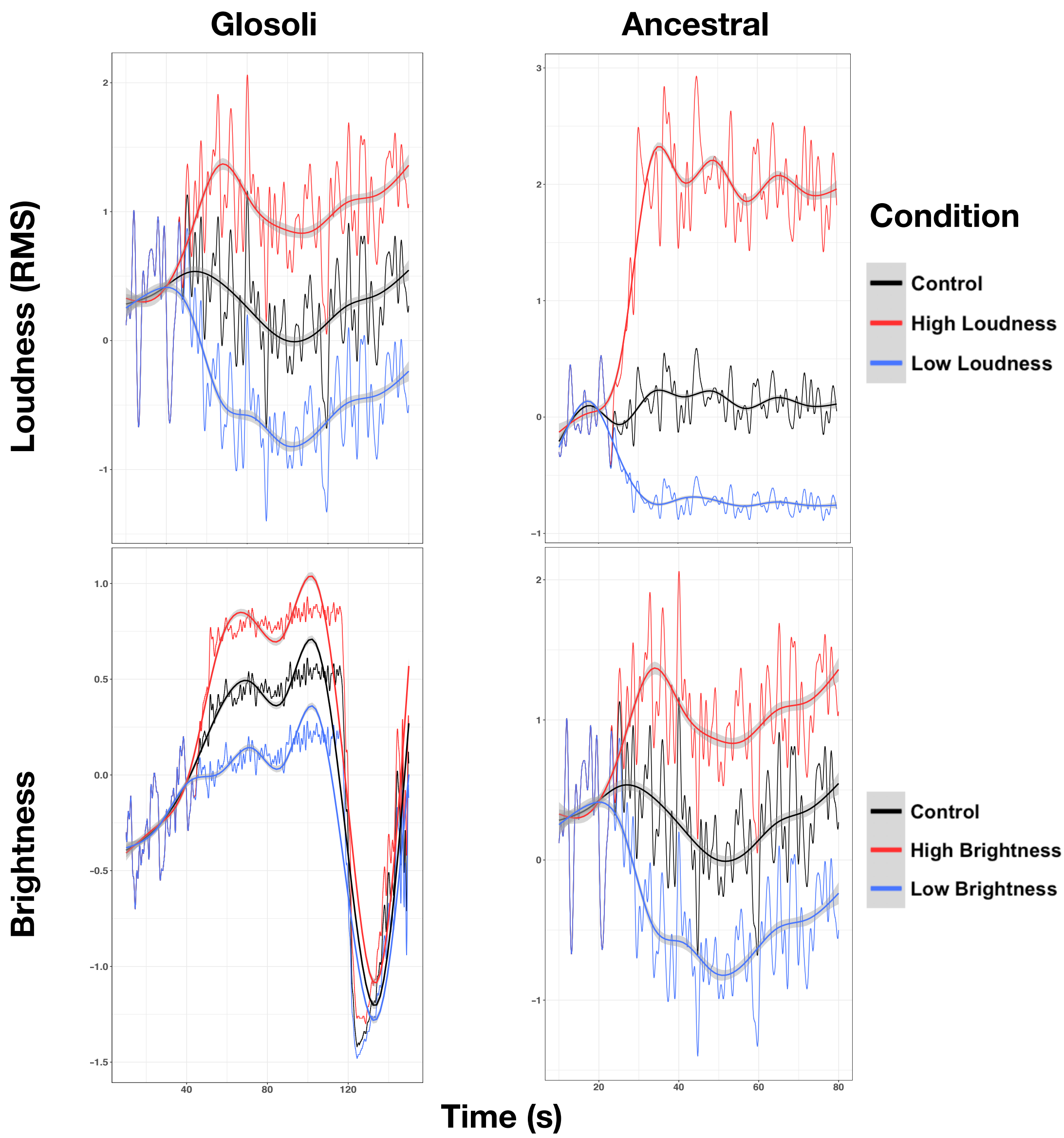

Figure 6.2: Time-series of loudness (first row) and brightness (second row) values for Glósóli (first column) and Ancestral (second column). Loudness is presented across control and loudness manipulations, whilst brightness is presented across control and brightness manipulations. Smoothed trend lines are a result of fitting a generalized additive model to the time-series data.

6.2.4 Procedure

Participants were tested separately, and assigned to one of the two stimuli groups (five stimuli in each group, one for each manipulation category); the experiment was administered via a laptop, using OpenSesame software. Participants were first asked to familiarise themselves with the experimental procedure, tasks and data management statements provided via an information form; informed consent was obtained through participants completing a short checklist of statements, and providing confirmation that they agreed to take part and understood the procedure. Before the main experiment, participants completed a few basic demographic questions, whilst electrodes were attached to the non-dominant hand to collect skin conductance data. As an important measure, participants were played a short excerpt of music at a level of loudness to match the maximum loudness in the experiment; participant and experimenter confirmed the most comfortable maximum volume to listen to this excerpt, to serve as a threshold for the remainder of the experiment. This not only served an important safety function, but also controlled for individual differences in loudness experience, by establishing a comparable perceptual threshold for all participants. All participants listened to the stimuli through headphones.

In the first phase of the experiment, participants listened to two excerpts, pressing a button whenever chills were experienced, and completing self-reports after each stimulus. Following this the BIS/BAS scales were completed, and served as a break from music listening; this break was included to limit any repetition or habituation effects, a crucial consideration when investigating strong emotional experiences. A further two excerpts were then presented to participants, with identical tasks and procedure to the first phase. Following these stimuli, the IRI instrument was completed, before participants listened to the final excerpt of the experiment.

Upon completion, participants could elect to join an experiment raffle, with a chance of winning one of three £20 Amazon gift vouchers. The experiment lasted approximately 25 minutes, and was fully approved by the University Ethics committee; all data were fully anonymised throughout the process.

6.2.5 Data Analysis

All data were processed fully or partially in the R environment (https://cran.r-project.org). For the BIS/BAS and IRI instruments, data were aggregated in accordance with distinct factor structures identified in previous research (Carver & White, 1994; Davis, 1983). Skin conductance data were pre-processed and analysed in accordance with the methods described in **Chapter 5**, with the use of the Ledalab package developed for MATLAB (Benedek & Kaernbach, 2010); in this instance, the phasic skin conductance response (SCR) was utilised as a more accurate, higher resolution indicator of event-related activity (Boucsein, 2012).

In the current analysis, SCR was used as a validation measure for the button presses provided by participants whilst listening. Following previous research, it was determined that a reliable self-report of chills should be accompanied by observable change in the SCR signal (Grewe et al., 2007). For this reason, an epoch comparison was carried out on the SCR data, such that if the SCR signal was significantly higher in the four seconds following a button press compared to a baseline period, then the chills report was retained for analysis; in this case, baseline periods were defined as a random 4 second sample from the 20 second epoch preceding the onset of the specific stimulus being analysed. As these comparisons (t-tests) were carried out for each of the button presses ($N = 329$), the statistical significance threshold was set to the lower value of $p < .001$, and significance values were Bonferroni corrected; this was to accommodate for numerous comparisons and strengthen the analysis. No button presses were retained that were registered before the point of psychoacoustic manipulation in the excerpts; this was to assess chills responses derived from specific manipulations of the stimuli. As a result, filtered button presses ($N = 129$) served as a primary dependent variable representing the frequency of chills experienced.

Additionally, average amplitudes of the SCR signal were calculated for the four second epoch following each validated button press, as an index of emotional intensity during chills; a four second window was selected in accordance with the documented lag structure of skin conductance, with a roughly two to three second response lag following an event or reported experience (Boucsein, 2012); these data were also normalised (*z*-scores) within participants to account for differences in response sensitivity across individuals (Khalfa et al., 2002). As a final measure of chills intensity, the duration of button presses was calculated and averaged within each listening condition; this is derived from a previous suggestion that chills of longer duration may indicate more intense emotional experiences (Craig, 2005).

6.3 Results

6.3.1 Frequency, Intensity and Duration of Chills

To calculate the frequency of chills responses across the ten listening conditions, button presses validated by phasic SCR peaks were aggregated and assessed as count data. Due to technical difficulties, no skin conductance data were collected for six participants, and so their button press data were omitted from the analysis. The descriptive statistics for overall chills experiences are presented in **Table 6.2**.

To analyse the count data, a general linear mixed effects model was developed using the '*lme4*' package in R (Bates, Mächler, Bolker & Walker, 2015), with a Poisson distribution; this model was fitted once for loudness manipulations, and once for brightness manipulations. In the model, the number of button presses served as the dependent variable, and listening conditions were fitted as fixed effects; the individual participants were fitted as random effects. For hypothesis testing, likelihood ratios tests were carried out, which utilised an ANOVA to compare the fitted statistical model to a reduced model (i.e. no listening condition component); this method enables the assessment of listening condition effects on the frequency of chills reports through general linear mixed effects models. For effect size indicators of the fixed effects in the models, marginal R^2 was calculated following methods from Nakagawa and Schielzeth (2013), using the '*MuMin*' R package (Barton, 2018).

Results suggest that for loudness manipulations, there was a significant overall effect on chills frequency (x^2 [2, 7] = 24.43, p = .0001, R^2 = .15). Further analysis found that increased loudness resulted in more chills for Glósóli (β = 1.09, SE = .49, z = 2.21, p = .02), which elicited more chills in listeners than any other conditions across the two pieces; interestingly, loudness manipulations had no effect for the control stimulus, Ancestral. For brightness manipulations, there was an overall effect of manipulation on the frequency of chills (x^2 [2, 7] = 31.85, p < .0001, R^2 = .34).

Table 6.2: Descriptive statistics of chills reports across conditions (note: no average SCR or duration was calculated for Glósóli high brightness, given only one chills report)

Piece	**Condition**	**Total Chills Reported**	**Average Normalised SCR**	**Average Button Press Duration (s)**
Glósóli	Control	11	.80	6.90
	High Loudness	29	.33	6.79
	Low Loudness	6	.21	6.66
	High Brightness	1	-	-
	Low Brightness	22	.42	8.17
Ancestral	Control	5	.65	5.57
	High Loudness	10	.19	9.80
	Low Loudness	11	.21	4.33
	High Brightness	16	.65	5.83
	Low Brightness	18	.20	3.10

More specifically, increases in brightness notably reduced chills across listeners for Glósóli (*ß* = -2.39, *SE* = 1.04, *z* = -2.29, *p* = .02); decreases in brightness increased the frequency of chills reports, although this was a non-significant trend (*z* = 1.58, *p* = .11). These effects are in opposition to those of loudness; high loudness and low brightness increased chills frequency for Glósóli, whereas low loudness and high brightness decreased chills frequency. Once again, no effects were found for any brightness manipulations in the Ancestral piece. The frequency of chills across pieces and conditions is visualised in **Figure 6.3**.

The next aspect of chills to be analysed was SCR amplitudes, treated here as an index of emotional intensity of chills. As the data were numerical, a linear mixed effects model was developed; SCR amplitudes were the dependent variable, listening conditions were fitted as fixed effects, and the individual participants were fitted as random effects. Importantly, as only one chill was reported for the high brightness condition for Glósóli, this was omitted from the analysis (see **Table 6.2**). Results suggest that there is no discernible difference in phasic SCR across the reported experiences of chills (x^2 [3, 11] = 11.66, *p* = .16); this appears to be the case across all manipulations and conditions for both experimental and control pieces.

The final aspect of chills considered for analysis was the average duration of reported experiences across listening conditions; this was a further index of chills intensity. However, as the high brightness condition of Glósóli resulted in only one chills report (see **Table 6.2**), no reliable value for duration was calculated, and therefore the condition was omitted from this part of the analysis. Like SCR amplitude, duration data were numerical and assessed with a linear mixed effects models; duration was the dependent variable, listening conditions were fixed effects, and individual participants were fitted as random effects. The mixed effects model highlighted no notable differences in chills duration across the different manipulations in the two pieces (x^2 [3, 11] = 9.43, p = .30).

To summarise results, the psychoacoustic manipulations had significant effects on the frequency of chills reports, although the experiences did not seem to vary with regards to indices of emotional intensity.

6.3.2 Self-Report Data

For each listening condition, participants also rated their experience on a series of self-report scales, including subjective feelings and bodily activity. Importantly, this data considers more general experiences of the manipulations in the experiment, and so data were not filtered by chills reports in this case. In terms of subjective feeling, participants rated their enjoyment of the music, alongside ten emotional descriptors. There were no significant differences found for emotional responses across the ten listening conditions, suggesting that the overall listening experiences were maintained across psychoacoustic manipulations. Generally, experiences across both pieces were similar; both were rated as enjoyable, moving and energetic; some nominal, non-significant trends include experiences with Ancestral being rated as more sad and nostalgic than Glósóli, and feelings of tenderness being more pronounced during Glósóli.

With regards to bodily activity, similar results were found, suggesting that there were no significant differences across pieces and listening conditions. The most common bodily responses reported across both Glósóli and Ancestral were feelings of coldness and smiling. The descriptive self-report data is available in **Appendix 3**.

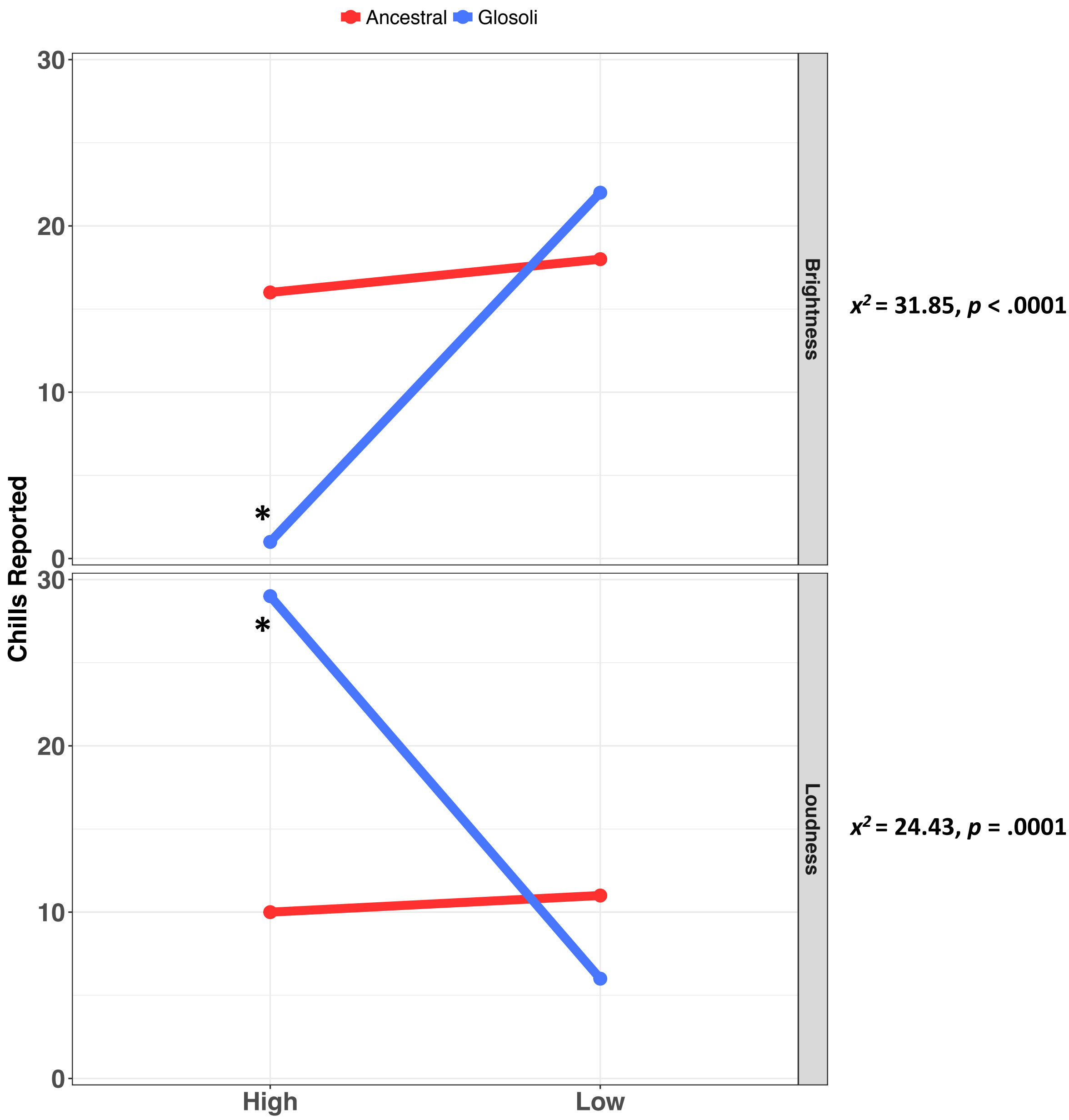

Figure 6.3: Differences in chills frequency across brightness and loudness manipulations for Ancestral and Glósóli (* = p <.05).

6.3.4 Empathy and Behavioural Activation/Inhibition

To assess how individual differences may mediate the experience of chills in response to music, trait empathy measurements derived from the IRI were assessed in relation to the frequency of chills reports by each participant. As chills frequency data did not follow a Gaussian distribution, spearman rank correlations were carried out to assess relationships with trait empathy; results suggest a small, non-significant relationship between chills frequency and trait empathy (r_s = .20, p = .13). Also, no significant relationships were found for subscales of trait empathy. In addition to trait empathy, behavioural activation (BAS) and inhibition (BIS) characteristics of the listeners was assessed; with the same correlation method, no relationship was found between BAS and chills frequency (r_s = .04, p = .40) or BIS and chills (r_s = -.13, p = .79). As previous research suggested that reward sensitivity was linked to chills (Mori and Iwanaga, 2015), a further analysis was carried out for the sub-facets of BAS; however, no significant relationships were evident, notably between reward sensitivity and frequency of chills reports (r_s = -.19, p = .87).

6.4 Discussion

Existing work has suggested a relationship between increased loudness and the elicitation of chills (Grewe et al., 2007; Panksepp, 1995; Sloboda, 1991). In addition to loudness, higher levels of spectral brightness (proportion of frequency energy above a stated threshold) have been shown to correlate with continuous ratings of chills intensity in the previous chapter of this dissertation. These parameters have been explored in studies on emotional expression in music (Caclin, McAdams, Smith & Winsberg, 2005; Eerola, Ferrer & Alluri, 2012; Hailstone et al., 2009; Juslin, 2000; Laukka, Eerola, Thingujam, Yamasaki & Beller, 2013), but are rarely considered in the context of induced emotion. From a theoretical perspective, it is intuitive to approach loudness increases and their associations with chills in terms of the vigilance theory. More specifically, the link between chills, loudness and crescendos may be explained by auditory looming (Ghazanfar et al., 2002; Neuhoff, 2001; 1998), where a sound increasing in loudness may be perceived as an approaching object, and something that demands heightened attention and vigilance given the possibility of threat or danger. A similar process may underlie associations between increased brightness and musical chills previously, although this has yet to be verified in auditory looming literature.

The current experiment tested, for the first time, the vigilance theory of musical chills, and the possible role of auditory looming mechanisms. Results suggested that whilst psychoacoustic manipulations did not affect the overall music listening experience, the frequency of chills experiences was significantly affected by both loudness and spectral brightness manipulations. Chills were elicited significantly more frequently when loudness was increased in the *experimental* stimulus (Glósóli), but not for the *control* stimulus (Ancestral); an opposite overall effect was found for spectral brightness, with chills elicited more frequently when brightness was decreased in Glósóli, whilst again no changes were found for Ancestral. Regarding individual differences, no relationships were found between the number of chills experienced and behavioural activation, behavioural inhibition, or trait empathy. Overall, the results offer partial support for the vigilance hypothesis of musical chills, but what follows is a discussion aimed at addressing why increasing loudness and brightness may not straightforwardly affect chills experiences, and at highlighting the important interactions between lower-level features and the underlying musical structure.

Loudness Manipulations

In the current experiment, by increasing loudness at the onset of a 'chills section' in music identified in the previous chapter of this project, the frequency of chills reported by participants was significantly increased for the experimental stimulus, namely Glósóli. Notably, when loudness was increased for the control stimulus Ancestral, there was no significant increase in occurrences of chills across listeners. The results for Glósóli in this case strongly support the vigilance theory of chills, such that salient changes in music, which in this case tap into auditory looming processes, may elicit an unconscious, immediate vigilance response in the face of 'threat', eliciting the evolutionary threat signalling function of goosebumps (Darwin, 1872); it was shown here that the more pronounced the increase of loudness is for this piece, the more frequently experiences of chills are reported, explained by an amplification of auditory looming mechanisms. Notably, the reduction of loudness did not affect the chills response when compared to the control condition of Glósóli; one explanation for this is that this manipulation still represents a salient change that attracts attention and vigilance, possibly implicating other related mechanisms such as brain stem reflexes (Juslin & Västfjäll, 2008); this is in some way reflected in recent work that suggested the phasic skin conductance response was more pronounced in response to loudness decreases, as opposed to increases (Olsen & Stevens, 2013). Additionally, this finding may explain the similarity in skin conductance amplitudes across chills experiences in the current study.

The most interesting consideration for loudness however is the lack of effect found for Ancestral. To explore this distinction, it is important to consider, from the outset, the underlying musical structure of these pieces, an essential factor for qualitatively designating an experimental and control stimulus in this experiment. For Glósóli, the excerpt was characterised by a gradual build up in textural density and dynamics, followed by a sudden dynamic increase and textural change. Notably, this piece was already suited to elicit chills via processes of fear, attention and vigilance, and loudness manipulations may have directly emphasised or diminished this. On the other hand, Ancestral can be characterised as a standard rock band setup, starting with sparse high vocal melodies, transitioning then into a virtuosic guitar solo that remains, for most of the excerpt, the prominent instrument and melody. Interestingly, whilst this excerpt is also effective at eliciting chills, the introduction of a guitar solo is not easily explained by vigilance theories. An alternative explanation may be that the guitar solo resembles an expressive human voice, resembling Juslin's (2001) description of 'super-expressive' instruments, through which chills can be elicited through processes of social bonding or empathy between listener and music (see Fiske et al., 2017, and data from **Chapter 4**). Crucially, the underlying structure of Ancestral does not seem well equipped to elicit chills linked to vigilance theory, and there may be a disjunction between this structure and the loudness manipulations aimed at activating and emphasising these processes. The interactions between lower-level and higher-level features of music is an area of notable complexity (McAdams, Vines, Vieillard, Smith & Reynolds, 2004), and indeed, similar conclusions were made with regards to musical chills in **Chapter 5**, suggesting that whilst certain moments in music may be particularly effective at eliciting the response, it is likely that these moments are empowered by their relationships with preceding structural developments in the piece.

Brightness Manipulations

In comparison to loudness, opposite effects were found for manipulations of brightness, such that decreases in brightness resulted in more frequent chills experiences for Glósóli. This is perhaps surprising considering previous correlations between brightness and musical chills presented in the previous chapter, although it must be noted that these relationships have been documented less consistently compared to loudness in the extant literature. However, whilst increases in brightness may elicit auditory looming processes, such that higher frequencies imply closer proximity, this has currently not been evidenced in auditory looming research, and could be a subtler effect than the dynamic increases produced by approaching entities or objects; indeed, results for Glósóli suggest that this might not be the case. Like loudness manipulations however, no effects of brightness were found for Ancestral. Given previous correlations between brightness and musical chills, differing trends of effect between the two pieces, and the seeming disconnection between brightness and vigilance processes underlying chills, an alternative explanation may be required, namely in the form of linking chills to social bonding theory.

In the social bonding context, brightness might imply closer proximity between oneself and another source or entity, but rather than activating vigilance processes, this proximity may instead be social, a form of intimate or communal closeness between oneself and another. A striking example of this is found in a related phenomenon of autonomous sensory meridian response (ASMR), described in **Chapter 3**. Pertinent to this study, among the common elicitors of ASMR include people or actors speaking quietly and closely into a sensitive microphone, in some instances whispering (Barratt & Davis, 2015). These sounds may be characterised by higher levels of brightness, and in turn portray a certain social intimacy, proximity and connection. By assessing brightness and its link to musical chills from this perspective, a scenario may be occurring that is comparable to loudness. In other words, the guitar solo in Ancestral may be better suited to elicit chills through social bonding processes, whereas Glósóli is not; by extension, increases in brightness, if linked to social processes, may compliment Ancestral and affect chills responses more readily, but not Glósóli. Furthermore, if Glósóli is predisposed to elicit chills through auditory looming mechanisms, then decreases of brightness may enhance these processes by suppressing auditory characteristics linked to social proximity and intimacy that may interfere to some extent. The current data suggest that this could be the case. However, it remains important to note that no clear, significant differences were found for any brightness manipulation in Ancestral, and that these explanations, for the most part, remain speculative.

Limitations

There are several limitations worth highlighting regarding the current study. Firstly, given the novel approach of manipulating psychoacoustic parameters in real musical stimuli to affect induced musical emotions, a level of control was difficult to extend across all features in the auditory stimuli such as roughness and flux; as a result, it is not trivial to confirm the effects of loudness in complete isolation. However, the relationships between loudness, roughness and flux might reflect ecologically valid perceptual experiences, and these parameters contribute in similar ways to valence and arousal expressions in some music (Eerola, 2011); also, in the case of loudness and roughness, both aspects have been linked to chills (Grewe et al., 2007; Nagel et al., 2008), and both may be applicable to ideas of vigilance mechanisms (Arnal et al., 2015; Ghazanfar et al., 2001; Huron, 2006). Importantly, the study demonstrated that loudness and brightness could be manipulated independent of each other, suggesting that separable perceptual composites were assessed in relation to musical chills; furthermore, inferences can still be made from the current results regarding the direct effects of loudness and brightness on musical chills. Secondly, as only two pieces of music were utilised in the current experiment, further research will be required to generalise the findings across a broader selection of structural and psychoacoustic contexts. It remains a complex task to elicit and manipulate chills in experimental settings, but some possible progressions could be to work with high quality MIDI excerpts, or originally compose musical stimuli, which would allow for greater control of manipulations, and in turn allow for more nuanced investigations into other mechanisms implicated in vigilance theory, such as brain stem reflexes and syntactical expectations in music; a necessary caveat however is whether artificial or originally composed music would be sufficient to induce strong experiences such as chills. Therefore, it was deemed important to develop the current causal paradigm using real pieces of unfamiliar music extensively validated as effective elicitors of chills in the previous two chapters, with some compromises made in terms of control.

6.5 Summary

To conclude, this study presents novel evidence for processes of auditory looming and vigilance underlying the musical chills response, providing a first causal test of any theory of the musical chills phenomenon. However, whilst there is now causal evidence for vigilance processes underlying chills, shown through increased loudness resulting in a higher occurrence of chills across listeners, this was only the case for one excerpt in the experiment, suggesting two interrelated key points: Firstly, there are important interactions between psychoacoustic, lower-level features and higher-level structural features (such as crescendos) that need to be considered and explored; and secondly, that vigilance processes may only underlie a certain of proportion of musical chills responses, with others possibly linked to social and empathic processes which further interact with the psychoacoustic and structural intra-musical relationships. Future work should attempt to develop more sophisticated approaches to psychoacoustic manipulations in emotion induction paradigms; additionally, further research should delineate the theoretical discourse surrounding chills, and investigate the different potential routes of induction, and how these relate to different musical and psychoacoustic features.

7. Distinct Varieties of Aesthetic Chills in Response to Multimedia

7.1 Overview of the Study

In the previous two chapters of the current dissertation, two listening experiments were carried out, that successfully developed a viable causal manipulation paradigm for the musical chills phenomenon. By building on a preliminary corpus of music derived from the survey in **Chapter 4**, chills sections in music can be identified and removed to suppress the response; furthermore, a more nuanced manipulation can be performed with psychoacoustic features, such as loudness and spectral brightness. By developing this paradigm, the research can begin to causally test existing theories of chills.

However, there are several inconsistencies across the experiments in **Chapter 5** and **Chapter 6**, mirroring levels of variation reviewed in **Chapter 3** and reaffirmed in **Chapter 4**; these are especially pertinent with regards to the third and final research aim of this dissertation concerning the conceptualisation and construct of chills. The previous chapter offered partial support for the vigilance theory of musical chills, with increased loudness resulted in more chills across participants for one piece; however, there were no effects for the second piece in this experiment, suggesting that psychoacoustic parameters linked to vigilance processes are not consistently effective alongside different musical structures. A comparable scenario was presented in the experiment of **Chapter 5**, where chills were suppressed in two of the three pieces of music, by removing chills sections consisting of different key features, such as a crescendo, famous string theme or guitar solo. In both experiments, a common interpretation was that there are complex interactions between moments in music that elicit chills and the preceding musical developments, and that psychoacoustic parameters interact in multifaceted ways with differing, underlying musical structures. On the other hand, these inconsistencies or differences across results can be interpreted with regards to different theories of musical chills; for example, different musical features may tap into potentially distinct induction routes of the response, with crescendos eliciting chills through vigilance mechanisms, and lyrics or 'super-expressive' instruments (Juslin, 2001) inducing chills through social bonding mechanisms. In **Chapter 5**, the piece Jupiter may have been less susceptible to structural manipulation due to familiarity and additional extra-musical factors (such as memory or conditioning), which may still be effective elicitors of chills but linked more to social processes, as opposed to musical structure and vigilance. Similarly, in **Chapter 6,** the piece Ancestral, with its guitar solo, may have been predisposed to social bonding chills, which is why the piece was resistant to all psychoacoustic manipulations that were theorised to activate vigilance processes such as auditory looming. These conclusions are only exaggerated in the context of findings from **Chapter 4**, in which substantial variety was found regarding emotional characteristics of chills, music linked to the response, and specific features in music that elicit chills. With the possibility that distinct psychological mechanisms underlying certain chills responses, encapsulated by vigilance and social bonding theories, it is possible that the experiences themselves are phenomenologically distinct in some ways; these distinctions have been alluded to in previous research (Levinson, 2006; Panksepp, 1995; Pelowski et al., 2017), but have rarely been assessed in aesthetic contexts (see Maruskin et al., 2012).

These possibilities are important for conceptual and theoretical approaches to chills; if the phenomenon of chills is not a unified construct, then there are far reaching implications for existing research and theory. Firstly, correlational studies of musical chills may have presented misleading conclusions if certain musical features or stimuli are more effective in eliciting certain chills experiences over others that have not been specified; with consistent use of classical music stimuli in musical chills studies, this could result in an over-representation of certain relationships between musical structure and chills, and not others such as lyrics and the human voice. Secondly, should there be significant distinctions between chills responses, there is the issue of individual differences such as personality; one immediate example would be the common conclusion that openness to experience is linked to the general experience of chills with music (Colver & El-Alayli, 2016; McCrae, 2007; Nusbaum & Silvia, 2011), when in fact the personality trait may instead be associated with certain variations of the chills response, and not others. Finally, if the conceptualisation of aesthetic chills experiences is currently unsuitable and inaccurate, then the causal testing of existing theories cannot develop coherently, meaning that certain hypotheses might be disputed or disregarded, mainly due to errors or inconsistencies in understanding what exactly is being investigated.

An immediate comparison that emphasises the general limitation of any one theory of musical chills, and consequently the conceptualisation of chills as a unified construct, is that between music and other aesthetic engagements, such as film, poetry, images and texts. As discussed in **Chapter 3**, chills can be elicited by a great variety of stimuli beyond music (Goldstein, 1980; Grewe et al., 2010; Schubert et al., 2018; Schurtz et al., 2012; Wassiliwizky et al., 2015; Wassiliwizky et al., 2017b), and this extended literature can contribute to understanding the phenomenon. However, in the broader context of multimedia, the vigilance theory of chills often struggles to explain chills in response to tragic films, poetry, and even the effects of lyrics as noted in

Chapter 4. In these cases, the social bonding theory of chills may be better suited, in which people may experience intensified communal sharing relations (CSRs), a level of bonding activation that crosses over to neurologically close and intertwined thermoregulatory goosebumps responses. In contrast, this theory may not be optimal for explaining links between chills and crescendos or sudden textural or harmonic changes in music, although this has yet to be thoroughly explored. Therefore, investigating the chills phenomenon in a broader multimedia context could be an essential, exploratory starting point to assess whether chills are a unified construct within aesthetic engagements; in turn, this endeavour may help to inform musical chills experiences more specifically.

One approach to understanding these differing processes that might underlie chills, is to assess phenomenological differences reported by participants during chills experiences; this may be in terms of both physical or bodily activity and subjective feelings. Differences in bodily activity, and the location of activity, have recently been linked to numerous different emotional and affective states (Nummenmaa et al., 2018), and studies on chills also note that the typical physical sensations of shivers, goosebumps and tingling can occur alongside other activity such as tears (Wassiliwizky et al., 2017a), warmth in the chest (Algoe & Haidt, 2009; Fiske et al., 2017), and other activity as presented in the first survey of the current project. Subjective feelings may also differ across chills, suggested in a handful of previous studies (Grewe et al., 2010; Nusbaum et al., 2014), and in the survey of the current project. Furthermore, chills have occasionally been linked to different affective concepts, such as awe (Konečni, 2005; Schurtz et al., 2012), peak pleasure (Blood & Zatorre, 2001), and being moved or kama muta (Benedek & Kaernbach, 2011; Fiske et al., 2017; Menninghaus et al., 2015; Wassiliwizky et al., 2015).

Therefore, the main aim of the current study was to empirically investigate the chills phenomenon and possible variations in the experience, using a variety of stimuli in different modalities and of different thematic qualities. A further aim of this study was to elucidate some of the possible underlying mechanisms of chills more broadly; for example, in the case of social bonding theories of the response, assess whether nuances in the chills experiences align with differing induction routes of being moved, such as *shared experiences* (Fiske, 2004), or *empathic concern* (Zickfeld et al., 2017). If the chills response is linked to different states such as awe, being moved and peak pleasure, variations in the response should be observable in reported subjective feelings, physical reactions and bodily responses attributed to chills. Finally, given the established links between being moved and trait empathy (Eerola et al., 2016), and the adjacent relationship between being moved and chills (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2015), links between empathy and the chills responses were explored.

The main hypotheses of the study are as follows:

- **H1**: Distinct categories of chills experiences would be established, derived from differences in subjective feeling and bodily activity reported.

- **H2**: The distinct chills categories would be consistently related to certain thematic qualities of the stimuli.

- **H3**: Trait empathy would be associated with the categories of chills experiences.

7.2 Methods

7.2.1 Design

A web-study was designed to assess the experience of aesthetic chills in response to 15 multimedia stimuli, across five modal categories (images, videos, texts, music, and music performance videos). These stimuli were derived from both the previous three chapters of this dissertation, and an online internet forum dedicated to content that elicits what is labelled frisson, on the social media website Reddit (www.reddit.com/r/frisson). On this forum, users submit a variety of multimedia content that gives them the experience of frisson, and other users can discuss and comment on the content, with each user being able to cast a vote for each item (+1 for good, enjoyable or effective elicitor, and -1 for the opposite); this provides a user-generated hierarchy of effect across the thousands of items uploaded to the forum, with presumably the most effective elicitors of frisson voted to the top of the rankings.

The study followed a repeated-measures design, with each participant responding to one random stimulus from each of five modal categories in a randomized order, resulting in five stimuli in total. After each stimulus participants were asked to confirm a chills response, and answer questions about their experience. The study was approved by the University Ethics Committee, written informed consent was obtained from all participants, and the use of Reddit complied with their user agreement and content policies as of September 24, 2018. The descriptive statistics for the participant sample, and full stimulus descriptions are available in **Appendix 4.** Complete raw data for this study has also been made available through Harvard Dataverse (see List of Publications section).

7.2.2 Participants

A total of 179 participants took part in the study, of which 114 were female, 52 were male, five were transgender or other, and eight did not provide gender data. The mean age of the sample was 30.91 (SD = 11.20, range = 18 – 74). Most the sample was comprised of students of different ages and level of education (52%), although a variety of occupations were reported (administration = 10%; healthcare and nursing = 9%; teaching = 6%; management = 6%). Numerous different nationalities were also represented in the sample (British and United Kingdom = 51%; German = 8%; American = 6%; Canadian = 3%), and participants listened to the study audio through several modes (computer speakers = 54%; headphones = 32%; desk speakers = 3%; unspecified = 11%). On a scale of one (*very high proficiency*) to five (*very low proficiency*), all participants reported being proficient with English language and comprehension (M = 1.31, SD = 0.54), with no participant reporting less than a moderate proficiency level (no ratings higher than three).

Participants were invited to take part in the study through social media outlets, such as Facebook, Twitter and institutional mailing lists; participants were not recruited through the Reddit 'frisson' forum, to reduce levels of familiarity with the stimuli that might confound results. The focus on chills experiences was an explicit part of the study advertisements; this possibly resulted in a specialized sample of the population (i.e. chills responders); this characterisation was further supported through 102 participants reporting that they experience aesthetic chills roughly between monthly and daily in their lives (from a possible five categories of *yearly, every few months, monthly, weekly* and *daily*). However, this sample specification was considered a vital approach to maximise the elicitation of chills, given the current aims of exploring and elucidating distinctions between different chills experiences, and the general rarity of the response in empirical settings and procedures.

7.2.3 Stimuli

A total of 15 stimuli were selected for this study, with images, texts, videos, music performance videos (MVs), and music excerpts chosen according to specific criteria: Firstly, for any video or MV stimulus, the item would need to be of an appropriate duration for the study, and if not, the stimulus would need to provide a meaningful and representative epoch to be extracted from the video (i.e. a contextualised narrative or topic that is clearly communicated). Stimulus durations were determined through an initial pilot test (N = 11), to validate the chills efficacy of the material; feedback from this procedure suggested that music, videos and MVs could be of one minute or less and still effectively elicit chills, which was important for reducing fatigue and length of the overall study, especially considering the focus on intense emotional experiences. Furthermore, participants in the initial test noted that as images and texts did not change over time like other stimulus types, presentation times of more than 20 seconds induced boredom, with the chills response often occurring during within this timespan. Therefore, music, videos and MVs were presented to participants for between 45 to 60 seconds, judged to be enough time to depict meaningful events or narratives, and control for fatigue; in contrast, images and texts were presented for 20 seconds.

Secondly, the three highest rated stimuli for each modal category on the online forum were to be selected following the suitability check criteria and process. For the musical excerpts, the three stimuli used in **Chapter 5** were chosen, with excerpts from identified chills sections in these pieces used for the current study (each

56 seconds). Thus, the stimuli ranged from instrumental music and amateur recordings of live performances, to images of war veterans, orphaned gorillas, and videos of scientists observing a successful landing of a rocket (see **Table 7.1**). Stimulus modality was not a central question for the current research as the existing literature, whilst highlighting that chills can occur across many sensory modalities, suggests little reason to anticipate systematic differences in chills experiences across modalities (Grewe et al., 2010; Maruskin et al., 2012). However, a diversity of modality was crucial to explore extensively, and with more clarity, the effects of stimulus qualities as opposed to modal artefacts on the broader chills response. Consequently, the data-driven thematic qualities and characteristics of the stimuli, and their impact on different chills experiences, was the focus.

7.2.4 Materials

Self-reports formed the primary source of data for the current study. After exposure to each stimulus, participants were asked to confirm whether they experienced something they would describe as chills (yes/no/unsure), and how familiar they were with the stimulus (Likert scale of 1 to 5); additionally, participants could confirm the experience of specific bodily activities (change in breathing, cold, frowning, goosebumps, laughter, lump in the throat, shivers, smiling, tears, tingling, warmth and warmth in the chest) with either yes or no answers, and provide various emotional ratings on Likert-type scales of 1 - 7 (affection, anger, calm, energetic, happy, inspired, intensity, melancholy, moved, nervous, nostalgia, relaxed, sadness, stimulated and tender). Bodily activity and emotion rating selections were motivated by findings in existing research (Algoe & Haidt, 2009; Fiske et al., 2017; Maruskin et al., 2012; Nummenmaa et al., 2018; Wassiliwizky et al., 2017a; Zentner et al., 2008).

Once participants had been exposed to the five stimuli randomly selected, the Interpersonal Reactivity Index (IRI) was completed, to assess relationships between trait empathy and the different experiences of chills. This instrument contains 28 items answered on 5-point Likert scales that range from 'does not describe me well' to 'describes me very well'. The psychometric structure of the instrument is comprised of four sub-scales or factors, labelled fantasy, empathic concern, perspective taking and personal distress. The instrument has been widely used and tested for reliability, internal consistency and validity (Davis, 1980; 1983), and been shown to be applicable across different languages (Braun, Rosseel, Kempenaers, Loas & Linkowski, 2015; De Corte et al., 2007). The study was administered via the Qualtrics platform.

7.2.5 Procedure

Participants were first presented with an information screen documenting the procedure of the study, followed by an opportunity to provide informed consent. Following this, participants were made familiar with the tasks in the study by presenting a practice image (a Cathedral); the task was to watch or listen to the stimuli presented to them, and to rate their physical and emotional experience afterwards. Once participants were happy to continue, they proceeded through five stimuli, one from each modal category. After the fifth and final stimulus, participants completed the IRI instrument. The study concluded by debriefing participants on the main hypothesis of the study regarding distinct types of chills experiences, and were offered the opportunity to be placed into a study raffle, with a chance of winning one £50 Amazon gift voucher. It is important to note that due to the focus on how individuals conceptualise the chills response, the limitations in existing research regarding the theoretical underpinnings and psychological construct of chills, and work by Maruskin et al. (2012) suggesting differences in experience between goosebumps and shivers, participants were not provided with a working definition of the phenomenon until the study had concluded; this was to ensure that participants were not artificially biased towards reporting any specific conceptualisation of chills experiences, allowing the study to explore meaningful, informative variations in how respondents characterise and report the phenomenon. The study lasted approximately 15 minutes.

Table 7.1: The 15 stimuli used in the web-study; the *thematic category* labels are derived from a data-driven, agglomerative hierarchical cluster analysis (see Data Analysis and Results sections of the current chapter)

Stimulus	Modality	Thematic Category	Description
Funeral Haka	Video	*Communion*	School students performing the Haka at teacher's funeral
Dog Reunion	Video	*Love and Gratitude*	Dog and owner reunited after long separation
Scientists	Video	*Communion*	Scientists celebrate landing of rocket
Jupiter	Music	*Solo Voice or Instrument*	Famous string theme from Gustav Holst
Ancestral	Music	*Solo Voice or Instrument*	Guitar solo from Steven Wilson
Glósóli	Music	*NA*	Large crescendo from Sigur Rós

Queen Audience	Music Video	*Communion*	Audience sings along to recording of Bohemian Rhapsody
Swiss Band	Music Video	*Communion*	Fans sing to chorus of song, to performers' surprise
Ave Maria	Music Video	*Solo Voice or Instrument*	Man sings in empty shipping container
War Veteran	Image	*Distress and Support*	Older man in distress walks alone during war memorial
Innocent man	Image	*Distress and Support*	Man judged to be innocent after years of imprisonment
Gorilla	Image	*Distress and Support*	Orphaned gorilla comforted by person
Father Pride	Text	*Love and Gratitude*	Loving message from Father to son
Professor	Text	*Love and Gratitude*	Quite from professor about caring for oneself
Addict	Text	*Love and Gratitude*	Grateful message from recovering addict to paramedics

7.2.6 Data Analysis

Data analysis was performed in R. The IRI instrument scores were totalled to provide an overall trait empathy rating, and aggregated into the four underlying factors of the instrument. Furthermore, bodily activity data were treated primarily as count data, coded with 1 for bodily activity experienced, and 0 for no activity experienced; mean ratings for subjective feeling data were calculated, and alongside physical responses formed the main level of analysis. To assess the overall frequency of chills across modal categories of stimuli, Poisson regression was utilised to account for positively skewed, repeated-measures data. To analyse chills frequency data within each stimulus modality, chi-square tests were performed, given that each participant responded to only one stimulus from each modal category, meeting the assumption of independence.

To assess the first experimental hypothesis (**H1**) related to possible distinct constructs of chills experiences, an exploratory analysis strategy was devised to reduce bodily activity and subjective feelings to fewer, coherent components. Firstly, data were filtered to include only self-reported confirmed experiences of chills across the stimuli. If a participant reported no chills to a certain stimulus or was unsure as to whether chills were experienced, this response was removed from the analysis; this was a crucial decision to avoid conflating chills experiences with other unrelated affective responses, allowing for a more robust methodology and interpretability of results. Next, reports of bodily activity were chosen as the starting point for identifying differing components across chills responses; due to the count data and repeated-measures design, the method of multiple correspondence analysis (MCA) was utilized through the R package '*FactoMineR*' (Lê, Josse & Husson, 2008), with bodily activity as the main dependent variable. This method develops dimensions that best describe the variance in the data, with highly explanatory dimensions maintained for analysis and interpretation. An important note is that eigenvalues generated from MCA are generally smaller than more traditional factor analysis approaches, therefore as opposed to retaining eigenvalues of a value greater than one (Kaiser, 1960), Greenacre (2017) suggests that dimensions can be retained if they correspond to eigenvalues equal to or above one divided by the number of variables in question. Output from MCA highlights which bodily responses are best represented by the main dimensions, and produces eta^2 correlations between the dimensions and the data, with statistical significance determined by calculating *z*-test statistics; this results in preliminary categories and groupings in bodily activity data. In addition, MCA allows for the designation of supplementary variables, such as demographic or participant data; in this case, the subjective feeling rating scales were utilized as supplementary variables, to provide a preliminary visualization and interpretation of the relationships between the bodily activity dimensions and emotional responses. Following this process, identified bodily activity groupings were correlated with emotional descriptors through polyserial correlations; the outcome of assessing these relationships would be finalized distinct chills categories comprised of bodily activity and subjective feeling responses. Whilst the method is similar conceptually to principle components analysis, MCA is optimized to work with categorical, binary dependent variables, and repeated-measures designs (Le Roux & Rouanet, 2010).

To develop average scores for different chills categories, bodily activity data were first aggregated and converted to numerical data (e.g. for a specific chills category: no corresponding bodily activity = 0, experiencing two corresponding responses = 2); next, both physical and emotion rating ranges were standardized from

1 to 5, with chills category scores derived from averaging over the corresponding physical and emotion data developed through the MCA and polyserial correlations.

Finally, to investigate relationships between these chills categories and stimulus characteristics, data-driven stimulus themes and distinctions were established through an agglomerative hierarchical cluster analysis of the overall chills category ratings across individual stimuli; this utilised a Euclidean distance similarity matrix of the mean chills category scores. From these themes, a confirmatory analysis strategy was then employed, assessing the effects of stimulus themes (**H2**) and individual differences (**H3**) on the experience of different chills categories. To achieve this, linear mixed effects models were fitted using the '*lme4*' R package (Bates et al., 2015), with chills category scores as the dependent variable, stimulus themes and trait empathy fitted as fixed effects, and both participants and individual stimuli included as random effects; this method was selected to control for variance across individual approaches to the study, and for idiosyncrasies within specific stimuli. Statistical significance was established through likelihood ratio tests, by comparing the full statistical model with a reduced comparative model. This procedure was carried out three times for each chills category: Firstly, to assess the contribution of stimulus theme to the model (**H2**), secondly to assess the contribution of stimulus theme to the model (**H3**), and thirdly to assess the possible interactions between stimulus theme and empathy. As an extended assessment of these models, vuong tests were carried out using the R package '*nonnest2*' (Merkle, You & Preacher, 2016), to check that the models were sufficiently distinguishable for the tests.

7.3 Results

7.3.1 Descriptive Statistics

Across 179 participants experiencing 5 stimuli each, a total of 344 chills responses were reported, meaning that chills occurred in roughly 38% of experiences; given the rarity of chills responses, this suggests that the stimulus selection process was reasonably effective for a sample of chills responders, although it is important to note that this result is likely not indicative of chills prevalence across a broader population. With regards to the IRI trait empathy scores, mean total score out of a maximum of 140 was 89.35 (SD = 9.86); no significant differences between males (M = 87.20, SD = 11.72) and females (M = 90.04, SD = 8.88) were found for trait empathy (t = -1.51, df = 73.56, p = .13); additionally, no differences were found across the four trait empathy sub-scales (fantasy: t = -1.33, df = 72.44, p = .18; empathic concern: t = -1.13, df = 72.47, p = .26; perspective taking: t = -0.97, df = 71.32, p = .33; personal distress: t = -.184, df = 85.68, p = .06). Results showed that participants were mostly unfamiliar with the stimuli presented (M = 1.97, SD = 1.28, range = 1 - 5).

7.3.2 Frequency of Chills

To explore the general efficacy of various stimuli in eliciting the chills response, the frequency of chills experiences reported was first analysed across the modal category level (image, text, video, music, MV). The video category resulted in 99 chills responses, followed by 72 chills with MVs, 66 responses with images, 57 experiences with music, and 50 reports of chills with texts. Regarding differences in chills frequency across modalities, results showed that the only significant effect was found for videos ($\beta = 0.40$, $SE = 0.15$, z = 2.55, p = .01), suggesting that whilst images, texts, music and MVs elicited similar frequencies of chills, videos were more effective.

Extending the analysis, the frequency of chills was assessed within each stimulus modality, to see if specific stimuli were particularly effective at eliciting chills. Results highlight that only one category showed a significant effect of individual stimulus, namely music (x^2 [2] = 13.61, p = .001), with Jupiter (chills N = 31) being a more effective elicitor in the study, as opposed to Glósóli (N = 12) and Ancestral (N = 14).

Regarding gender, it was found that females reported more chills (N = 238) than males (N = 88); however, the sample was largely comprised of female participants, and Holm corrected comparisons suggested that this difference was not significant ($ß$ = 0.19, SE = 0.13, z = 1.47, p = .28).

7.3.3 Distinct Chills Experiences

To assess the first experimental hypothesis (**H1**), an exploratory analysis strategy was utilised; MCA was carried out across chills reports, with reported bodily activity as the main dependent variables, and subjective feeling ratings as supplementary variables. By visualizing the variances explained by dimensions using a scree plot, and utilising Greenacre's eigenvalue considerations (Greenacre, 2017), three dimensions were initially retained for analysis constructed from bodily activity data: the first dimension explained 16.23% of variance (eigenvalue = 0.16), the second dimension explained 12.68% of variance (eigenvalue = 0.13), and the third dimension explained 11.75% of variance (eigenvalue = 0.12); the total explained variance was 40.67%. For these dimensions, the eta^2 values are presented in **Table 7.2**. Results show that for the first dimension, significant medium strength correlations were found for frowning, smiling, feelings of warmth, and feelings of cold; for the second dimension, significant, medium strength correlations were found for tingling, shivers and goosebumps; finally, for the third dimension, significant, medium strength correlations were found tears and feeling a lump in the throat. It was anticipated that shivers and goosebumps might correlate more strongly with differently valenced dimensions (Maruskin et al., 2012); however, the second dimension was primarily characterized by bodily activity encapsulated by traditional conceptualizations of chills (goosebumps, shivers, tingling), a dimension that was judged to be unrevealing due to data being filtered to contain only chills experiences. For this reason, the first and third MCA dimensions formed the main source of interpretation. The first dimension was primarily characterized by coldness and frowning on one end of the axis, and smiling and warmth on the other; the third dimension was characterized mainly be the feeling of a lump in the throat, or experiencing tears during chills.

Supplementary variables comprised of emotion data were also plotted onto the first and third dimensions developed in the MCA (see **Figure 7.1**), suggesting that the first dimension was characterized by ratings of sadness, anger, happiness, energy and stimulation; the third dimension appeared to be characterized by ratings of being moved, tenderness, affection and emotional intensity. To assess the statistical relationship between bodily activity and subjective feelings, polyserial correlations were carried out between physical activities significantly correlated with the first and third MCA dimensions, and each emotional descriptor (see **Table 7.3**). Results showed that for warmth and smiling responses, significant medium to strong

Table 7.2: Eta^2 values for bodily activity data on the first three dimensions of the multiple correspondence analysis (medium to large correlations are marked in bold).

Response	Dimension 1	Dimension 2	Dimension 3
Smile	**.51**	.01	.02
Warmth	**.36**	.02	.00
Cold	**.29**	.01	.05
Frown	**.28**	.02	.06
Warmth in Chest	.23	.00	.07
Goosebumps	.04	**.49**	.00
Shivers	.00	**.41**	.03
Tingling	.01	**.39**	.00
Lump in Throat	.00	.00	**.57**
Tears	.00	.08	**.39**
Laughter	.12	.05	.04
Breathing	.05	.00	.14

correlations were found with happy, stimulated, and relaxed ratings; for coldness and frowning, significant medium to strong correlations were found with sadness and anger; finally, for lump in the throat and tears, significant medium correlations were found with affection, tenderness, being moved, and emotional intensity.

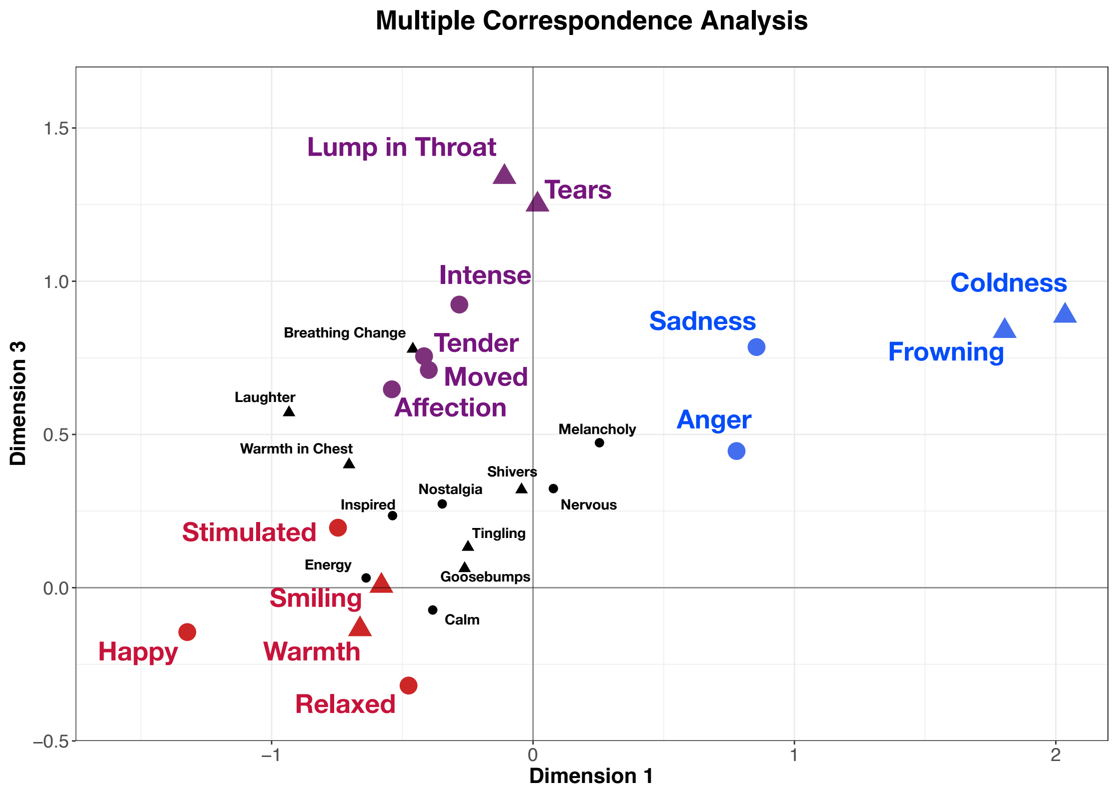

Figure 7.1: Visualisation of the multiple correspondence analysis. Shapes indicate physical (triangle) and emotional (circle) responses, and colours indicate the chills categories developed through MCA and polyserial correlations (red = *warm chills*, blue = *cold chills*, purple = *moving chills*).

Following the MCA and polyserial correlations, final distinct chills categories were constructed, characterized by groupings in, and between, both bodily activity and emotional experience data: *warm chills* (warmth, smiling, happiness, stimulated and relaxed), *cold chills* (coldness, frowning, sadness and anger), and *moving chills* (lump in the throat, tears, affection, tenderness, being moved and intensity). These aggregated, mean chills category ratings were not significantly different across gender, or familiarity ratings; furthermore, it is worth noting that adopting a more inclusive data analysis approach (i.e. retaining 'unsure' responses from participants regarding chills) produces comparable results.

7.3.4 Distinct Chills, Stimulus Themes and Empathy

In assessing the second (**H2**) and third (**H3**) experimental hypotheses, namely the effects of stimulus themes and individual differences on warm, cold and moving chills, an exploratory analysis was utilised, followed by a confirmatory analysis. First, an agglomerative hierarchical cluster analysis was performed on chills category ratings across the individual stimuli; by silhouette plotting and dendrograms, the optimal number of clusters to retain was two, which together portray a distinction between negative and positive valence across the stimuli (see **Figure 7.2**). By assessing the qualitative similarities between stimuli, the negative cluster stimuli could be categorized thematically in terms of expressions of *distress and support* (visible distress, injustice, support from one to another); the positive cluster stimuli could be characterized by three thematic qualities: *communion* (moments of group motor or vocal synchrony), *love and gratitude* (affection and messages of love), and *solo voice or instrument* (solo vocal performance, guitar solo or string theme). The excerpt Glósóli could not be thematically categorized, and was omitted from further analysis. Stimuli were henceforth organized into these thematic categories (see **Table 7.1**); this was to accommodate the unbalanced number of negative and positive stimuli, and to increase the level of resolution concerning stimulus qualities and content and corresponding effects, derived from the data-driven positive and negative two cluster solution.

Table 7.3: Polyserial correlations between main bodily activity variables from the multiple correspondence analysis, and emotional descriptors (medium to large positive correlations in bold text).

Response	Smile	Warmth	Cold	Frown	Lump in Throat	Tears
Happy	**.72**	**.50**	-.54	-.64	-.08	-.04
Stimulated	**.31**	.28	-.14	-.36	.05	-.03
Relaxed	.24	**.36**	-.13	-.19	-.16	-.25
Sadness	-.64	-.28	**.44**	**.51**	**.40**	**.40**
Anger	-.41	-.21	**.52**	**.67**	.20	.14
Affection	.14	**.40**	-.11	-.11	**.33**	**.41**
Tender	.09	.28	-.01	.02	**.37**	**.37**
Moved	.02	**.31**	-.12	-.08	**.39**	**.50**
Intensity	-.02	.16	.03	.02	**.42**	**.50**
Energetic	**.34**	.17	-.09	-.24	-.08	-.08
Calm	.16	.28	-.16	-.13	-.01	-.06
Inspired	.16	.24	-.22	-.22	.13	.07
Melancholy	-.25	-.08	.21	.21	.20	.17
Nostalgia	.003	.13	-.10	-.27	.10	.08
Nervous	-.14	-.09	.25	.10	.02	.06

For the confirmatory analyses, linear mixed effects models were fitted to data for each of the three chills categories to assess effects of stimulus theme and individual differences. Regarding effects of stimulus theme (**H2**), results for warm chills showed that stimulus theme had a significant effect on experience ($x^2 = 18.05$, $df = 3$, $p < .001$).

Holm corrected post-hoc comparisons showed that the theme of distress and support was rated significantly lower for warm chills compared to communion (*ß* = -1.40*, SE* = 0.25, *z* = -5.55, *p* <.001), love and gratitude (*ß* = 1.30, *SE* = 0.25, *z* = 5.06, *p* <.001), and solo voices and instruments (*ß* = 1.21, *SE* = 0.27, *z* = 4.43, *p* = .008). For cold chills, model comparisons showed a significant effect of stimulus theme on experience (x^2 = 31.27, *df* = 3, *p* <.001). Corrected post-hoc comparisons suggested that this effect of theme was driven by distress and support, which received significantly higher cold chills ratings when compared to communion (*ß* = 1.67, SE = 0.17, z = 9.35, *p* <.001), love and gratitude (*ß* = -1.70, *SE* = 0.18, *z* = -9.37, *p* <.001), and solo voices and instruments (*ß* = -1.58, *SE* = 0.19, *z* = -8.16, *p* <.001). Finally, results for moving chills showed that stimulus themes had a significant effect on experience (x^2 = 8.54, *df* = 3, *p* = .03); however, corrected post-hoc comparisons revealed only one significant difference between themes, with distress and support resulting in higher moving chills ratings, compared to solo voices and instruments (*ß* = -0.88, *SE* = 0.27, *z* = -3.13, *p* = .01). It is worth noting that carrying out these hypothesis tests at the level of positive or negative clusters of stimuli (as opposed to thematic categories) results in highly comparable effects, although no significant effect is found for moving chills (warm chills: x^2 = 17.41, *df* = 1, *p* <.001; cold chills: x^2 = 30.78, *df* = 1, *p* <.001; moving chills: x^2 = 3.10, *df* = 1, *p* = .07).

In relation to trait empathy (**H3**), for warm chills there was neither a significant effect of empathy on results (x^2 = 2.42, *df* = 1, *p* = .11), or significant interaction between theme and empathy (x^2 = 2.59, *df* = 3, *p* = .45). Concordantly, for cold chills there was neither a significant effect of empathy (x^2 = 0.55, *df* = 1, *p* = .45), or significant interaction between stimulus theme and empathy for cold chills ratings (x^2 = 3.42, *df* = 3, *p* = .33). For moving chills, as with warm chills and cold chills, there was no significant interaction between stimulus theme and empathy ($x^2 = 6.14$, $df = 3$, $p = .10$); however, there was a significant effect of empathy on moving chills ratings ($x^2 = 4.51$, $df = 1$, $p = .03$), with higher empathy scores resulting in higher mean scores for moving chills responses.

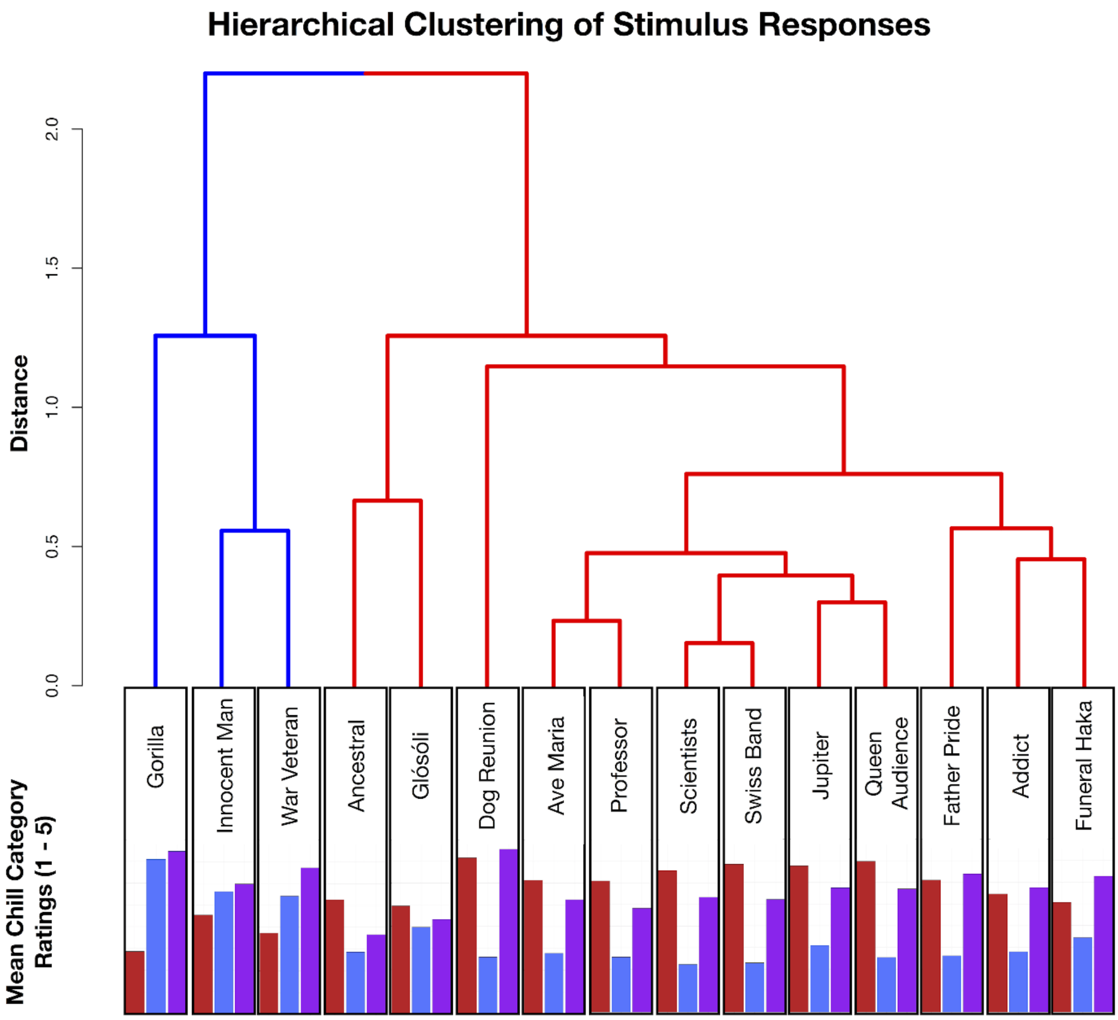

Figure 7.2: Full solution dendrogram from the agglomerative hierarchical cluster analysis. Red and blue branch colours indicate the two-cluster solution representing positive and negative valence; bar graphs indicate raw mean ratings for *warm* (red), *cold* (blue) and *moving* (purple) chills for each individual stimulus.

Alongside the cluster analysis, these results suggest that whilst warm and cold chills correspond to the positive and negative valence distinction, moving chills are experienced similarly across most stimuli, and that trait empathy characteristics may be important in predicting moving chills experiences. As a final assessment of the mixed effects model comparisons, Vuong tests were carried out with the R package '*nonnest2*' (Merkle, You & Preacher, 2016), to check that the models were sufficiently distinguishable for the tests. Results suggest that only one comparison involved models that were not significantly distinguishable, mainly the full cold chills model and corresponding reduced no empathy model; whilst there appears to be no clear association between trait empathy and cold chills ratings, this result should be approached with some degree of caution. The likelihood ratio test statistics and post-hoc comparisons are presented in **Table 7.4.**

7.4 Discussion

The current study aimed to assess the possibility of distinct chills experiences, as proposed by existing research (Levinson, 2006; Maruskin et al., 2012; Panksepp, 1995; Pelowski et al., 2017) and previous chapters of the current dissertation, and to further elucidate the possible underlying processes of the responses through analysing differences across stimuli. The identification of distinct categories of experience within the chills construct has important ramifications for existing research, and future investigations.

The present study highlighted three categories of chills responses. Firstly, *warm chills* were experiences accompanied by positively valenced feelings such as joy, stimulation and relaxation, and bodily activity such as smiling and feelings of warmth. These experiences were linked to stimuli depicting instances of social

Table 7.4: Likelihood ratio test statistics and post-hoc comparisons, to assess effects of stimulus themes and trait empathy on warm, cold and moving chills (*** = *p* <.001, ** = *p* <.01, * = *p* <.05).

Chills Category	**Fixed Effects**	**Likelihood Ratio (x^2)**	**Post-Hoc (Theme Comparisons)**	***z*-statistic**
Warm Chills	*Stimulus Theme*	18.05***	Distress and support < Communion	-5.55***
			Love and gratitude > Distress and support	5.06***
			Solo voice and instrument > Distress and support	4.43**
	Trait Empathy	2.42	---	---
Cold Chills	*Stimulus Theme*	31.27***	Distress and support > Communion	9.35***
			Love and gratitude < Distress and support	-9.37***
			Solo voice and instrument < Distress and support	-8.16***
	Trait Empathy	0.55	---	---
Moving Chills	*Stimulus Theme*	8.28*	Solo voice and instrument < Distress and support	-3.13*
	Trait Empathy	4.51*	---	---

communion, such as music audiences singing together or scientists celebrating together, and loving scenarios, including reunions between pet and owner or a message of pride from father to son. Secondly, *cold chills* were experiences accompanied by negatively valenced feelings such as sadness and anger, and bodily activity such as frowning and feelings of cold. Cold chills appear to be best elicited by stimuli that depict an instance of injustice, distress, and visible support from one person to another person or animal in need of help. Finally, *moving chills* were accompanied by bodily activity such as tears and a lump in the throat, and were characterized mainly by feelings of tenderness, affection, intensity, and being moved. These experiences appeared to be elicited frequently across most stimuli, but are the only responses significantly related to levels of trait empathy. These findings suggest that there exist at least three separable chills constructs, distinguished based on affective valence, qualities of the elicitors, and individual differences. Furthermore, it is inferred from the online forum source of the stimuli utilized, that both warm and cold chills are experiences pursued and sought after by a specific population, regardless of affective valence; however, future research should consider in more detail the hedonic experience of differing kinds of chills experiences, perhaps through replication of previous neuroimaging work (Salimpoor et al., 2011).

There are important implications for this preliminary distinction between warm and cold chills, particularly for research into states of being moved. Warm and cold chills appear to align with a distinction in the being moved construct between joyfully and sadly moving scenarios and experiences (Menninghaus et al., 2015; Tokaji, 2003; Wassiliwizky et al., 2015). In earlier work, Tokaji (2003) demonstrated that the same film clip could be sadly or joyfully moving, depending on the context provided; more recently, Wassiliwizky et al. (2015) suggested that joyfully moving experiences may be elicited by film clips in which a positive foreground event takes place within an overarching negative context (e.g. reunion after a long separation), and that sadly moving responses are linked to negative events within a positive context (e.g. self-sacrifice to save one’s family). Notably, a stimulus involving a reunion between dog and owner was strongly associated with positive, warm chills responses, indicating states of being joyfully moved; in contrast, a distressed war veteran marching alone in what appeared to be an anniversary parade, conveying new loneliness as the last surviving veteran, was a highly effective elicitor of cold chills responses. The significance of a phenomenological distinction between joyfully and sadly moving experiences is in the psychological processes underlying these responses, with additional implications for being moved and intensified communal sharing relations (CSRs; Fiske et al., 2017). Being moved may be elicited by observing the intensification of CSRs in others (third-person), by experiencing a CSR with another person or entity (second-person), or even through memories and internal processes related to CSRs (first-person); furthermore, the intensification of CSRs may be a result of many different processes, with *shared experiences* or *empathic concern* both portrayed in the stimuli used in the current study, and both linked to warm and cold chills respectively. For example, expressions of shared experiences in stimuli such as a large audience singing and moving to music, scientists celebrating together, or school students performing a Haka at their teacher's funeral, consistently resulted in reports of warm chills experiences and responses, which may be linked to processes related to social identity, belonging, bonding and closeness (Fiske, 2004). In contrast, stimuli expressing themes of distress, emotional discomfort, and a display of comfort or support being offered from one person to another person or animal, appear linked to empathic concern, a process previously associated with goosebumps, tears and warmth in the chest (Zickfeld et al., 2017), and presently to cold chills. In other words, warm chills may reflect joyfully moving scenarios, most effectively elicited by instances of shared experiences, whereas cold chills reflect sadly moving scenarios, consistently elicited by events that more readily invite empathic concern. This more detailed distinction suggests that whilst CSRs offer a broad psychological mechanism for various states of being moved, kama muta, and related emotional experiences such as nostalgia and elevation (Algoe & Haidt, 2009; Fiske et al., 2017; Wildschut et al., 2010), it is crucial to develop an understanding of the qualitative differences regarding how exactly CSRs are intensified, at what level, and how these differences may result in meaningful, phenomenological distinctions in emotional states such as being moved and related chills responses.

Although it is intuitive to distinguish between warm and cold chills in the current study, the third, moving chills category appears to be more complex. Moving chills were mainly categorized by intense bodily experiences such as tears and feeling a lump in the throat, emotional intensity, and feelings of affection, tenderness and being moved. The response appears to reflect a more prototypical conceptualization of being moved, a seemingly bittersweet, mixed emotional response with social underpinnings (i.e. tears with feelings of affection). The response was associated with most of the stimuli in the current study, although moving chills were also linked to differences in trait empathy across participants. Whilst one interpretation of the analysis could be that moving chills do not denote a separate category of chills, this does not appear to be the case, given that their bodily activity and subjective feeling responses grouped distinctly from other ratings, and that moving chills was the only category to be predicted by individual differences. The finding that moving chills were relatively prevalent across most stimuli further supports the interpretation of warm and cold chills as reflecting positive and negative nuances of broader experiences of being moved linked to socially or personally significant life events (Cova & Deonna, 2014; Kuehnast et al., 2014; Menninghaus et al., 2015). As trait empathy seemed important only for the moving chills category, this suggests that there is a significant role of individual differences in the experience of certain kinds of chills responses, with phenomenological aspects of chills potentially mediated by empathy. In other words, individual differences may not mediate or predict chills responses at the holistic level of incidence as previously reported; instead, individual differences may influence the phenomenological qualities and experience of chills, and influence which distinct psychological mechanisms may more commonly underlie the experience for certain people. This possibility may also explain null relationships between chills and trait empathy in **Chapter 6**; perhaps chills experiences linked to vigilance mechanisms, such as auditory looming, are not associated with empathy.

In line with the distinction between vigilance and social bonding theories of chills, this may be contextualised, especially with music, by a corresponding empathising-systemising distinction in listeners (Baron-Cohen & Wheelwright, 2004). As introduced in **Chapter 3**, this distinction suggests that systemisers tend to process formal structures, regularities, patterns and rule systems; in contrast, empathisers tend to identify emotions in other people or stimuli and respond in emotionally appropriate ways. By extension, if some individuals prefer to process music at the level of structure, pattern, repetition and syntax, then the aesthetic and emotional experience may tend to be derived from these aspects, such as dynamic changes, crescendos, expectancy violations or unprepared harmonies, all possibly linked to vigilance chills responses (Grewe et al., 2007; Huron, 2006; Sloboda, 1991). On the other hand, a listener may prefer to process music in terms of narrative (Margulis, 2017), social relationships (Aucouturier & Canonne, 2017), and personas or characters (Robinson & Hatten, 2012); instead, aesthetic and emotional experience might be derived from solo instruments, lyrics and the human voice, all aspects also linked to musical chills in the current dissertation.

Limitations

There are numerous limitations in the current study that are worth highlighting. Firstly, the web-study paradigm may have introduced confounds such as variations in concentration, attention and experience that were not possible to measure. Similarly, no objective measures of emotional experience were collected, meaning that the temporal correspondence between chills reactions and self-reported experiences could not be fully elucidated. However, the web-study was the optimal method for developing investigations into distinct chills experiences, especially given the lack of understanding, evidence and prior research that currently restricts more experimental, psychophysiological endeavours.

Secondly, there is the issue of allowing participants to approach chills with individualized conceptualizations of the response. Given that the conceptualization of chills was a central question of the current study, it was not advisable to provide a working definition to participants before the study, as would normally be the case. It is possible that participants reported chills experiences beyond the 'traditional' working definition, such as crying or feeling other sensations as opposed to goosebumps, shivers or tingling; on the other hand, given that there exists little research into the details and variations in what people describe as chills, attention should be given to the ways in which people describe and discuss these phenomenological responses. In other words, whilst there is a risk of increasing the range of descriptors and aspects of a chills experience to the scope of inconveniencing experimental approaches, variations in emotional response was the focus of the study, with numerous implications for existing and future research, and theoretical discourse underlying chills. Thirdly, when theoretically framing aesthetic chills in relation to evolutionary functions such as thermoregulation, it is important to note that it remains unclear how the chills phenomenon resembles or relates to mammalian goosebumps reactions, nor is it fully understood how engagements with multimedia are associated with thermoregulatory responses; further conceptual work would help to clarify how to situate aesthetic chills, for example by considering the role of goosebumps or shivers as symptoms in fevers and seizures (Briese & Cabanac, 1991; Stefan et al., 2003).

Finally, whilst different modalities were included in this novel investigation to enrich and extensively explore chills experiences, possible modality-specific effects were not controlled, and given the rating system of the web-forum used to identify suitable stimuli, some modalities, such as the images, were comprised only of negative themes and content. Although there is no immediate reason to suspect clear effects of modality on chills experiences (Grewe et al., 2010; Maruskin et al., 2012), future systematic work on the topic could utilise more stringent control measures for modality, possibly by ensuring a balance and equivalence of thematic quality or affective composition of stimuli across the modalities.

7.5 Summary

In conclusion, the current study provides the first investigation into the possibility of distinct chills experiences in response to various aesthetic stimuli and multimedia. Results suggest that preliminary chills categories may be distinguished by reports of bodily activity and subjective feeling, with warm and cold chills differentiated mainly in terms of affective valence qualities, and possibly underlying processes of shared experience and empathic concern respectively; this distinction reflects being joyfully and sadly moved, and supports the need for further detailed research into the experiences of being moved. Furthermore, the moving chills category appears to be prevalent across all stimuli used in the current study, but this seemingly more intense emotional response was the only category linked to higher trait empathy in participants. This third chills category and its relation to empathy highlights the importance of individual differences in chills experiences; furthermore, the findings suggest that the contextualization of the role of individual difference should be understood not in terms of whether chills are generally experienced or not in response to an aesthetic stimulus, but in terms of the tendency to experience certain kinds of chills over others. There are numerous avenues for future research with regards to aesthetic chills, such as exploring and elucidating the variety of chills responses in aesthetic engagements, such as awe-related states (Schurtz et al., 2012), testing existing fear and social theories of aesthetic chills, and to extend studies of individual differences through the assessment of personality, preference and empathy effects on the variations of chills responses reported. Finally, it is highly important to build on the initial chills distinctions presented in the current study, and to attempt to measure objective differences in chills responses that may contribute to understanding the psychological and evolutionary antecedents of chills experiences in aesthetic contexts.

8. Vigilance and Social Chills with Music: Evidence for Two Types of Musical Chills

8.1 Overview of the Study

Across the research agenda and development presented so far in the current thesis, a consistent conclusion or interpretation of results refers to the possibility of separable, distinct musical chills experiences. This possibility has been suggested and extended in the present research, to explain the wide variety of aesthetic engagements in which chills can be elicited, and the seeming inability for any existing theory of the phenomenon to explain and account for this variability. Findings from the current dissertation, and the extensive review presented in **Chapter 3**, indicate that distinct categories of musical chills better account for the existing literature, and accommodate two central theories of the phenomenon, mainly vigilance theory and social bonding theory.

The previous chapter explored more broadly, in a multimedia context, the separation of different, stimulus-driven chills categories and constructs, differentiated at the levels of accompanying bodily activity and subjective feeling components. However, whilst the results suggested, alongside considerations from Maruskin et al. (2012), that aesthetic chills can at least be separable at the level of valence, and that individual differences such as trait empathy may influence the quality of chills experienced, the final study of this project aimed to directly and empirically test the hypothesis that there are different types of musical chills, separable in terms of subjective feeling, physiological activity, elicitors and individual differences. Derived from the two main theoretical positions reiterated throughout the thesis, the following listening experiment therefore aimed to investigate a distinction between two categories of chills with music: Those elicited through processes of vigilance, and those through social bonding mechanisms.

8.2 Empirical Predictions

In the current formulation, two distinct types of musical chills are proposed, namely *vigilance chills*, and *social chills*, derived from the corresponding vigilance and social bonding theories of the phenomenon. Importantly, in a music listening context, it is proposed that these two types of chills can be distinguished and separated in accordance with several factors, such as the stimulus and experimental manipulation, self-reports of subjective feeling, psychophysiological activity, and individual differences across listeners; these propositions are derived from the several levels of variation found across extant work on musical chills (**Chapter 3**), and the previous four studies of this dissertation. What follows is a set of empirical predictions for each of these factors in relation to musical chills.

8.2.1 Stimulus Properties and Manipulation

Theoretically, vigilance chills should be elicited by features linked to mechanisms of expectancy, brain stem reflexes and auditory looming; these features may include crescendos, unprepared harmonies and sudden transitions or changes. In contrast, social chills might best be elicited by mechanisms of empathy and intensified communal sharing relations; important musical features may include the human voice, lyrical or narrative content, and numerous other aspects that have started to receive attention in this research project. At the level of stimulus and experimental manipulation, one possible approach to distinguishing musical chills experiences would be to utilise different pieces characterised by structural (e.g. harmonic violations) or narrative features (e.g. lyrics) respectively; however, this is problematic for causal inferences, as it would be difficult to ascertain whether the structural or narrative features were the primary aspects linked to chills, in contrast to the numerous other structural or psychoacoustic parameters that would not be controlled for.

Importantly, moments of *contrast* in music might be able to elicit both vigilance chills and social chills. Contrast and transition encapsulate many structural features linked to vigilance chills in previous research, such as crescendos and sudden dynamic changes (Grewe et al., 2007; Panksepp, 1995). Pertinently however, the idea of contrast is also pervasive in discussions of narrative, and communicating moments of narrative salience (Burnham, 2000; Graesser, Singer and Trabasso, 1994); this has more recently been explored through a paradigm developed by Margulis (2017), with moments of contrast in music possibly serving as auditory analogies to key moments in a narrative, not unlike scenes and events often linked to chills in film and poetry (Wassiliwizky et al., 2015; 2017b). In other words, contrast may engage either vigilance or social processes. Consequently, selecting musical excerpts with salient moments of contrast, such as a crescendo or dynamic change, allows for the possible manipulation of the same piece of music to bias listeners towards experiencing vigilance or social chills, in turn controlling for plethora of other structural and psychoacoustic aspects within the music. There are two possible manipulations to achieve this. Firstly, listeners could be provided with written information about the piece prior to listening, either emphasising the signposting of structural development in the music (i.e. vigilance), or describing a fictional, moving narrative that reflects the overall dynamic contour of the music (i.e. social); this approach has been found to influence the emotional experiences of listeners previously (Margulis, Levine, Simchy-Gross & Kroger, 2017; Miu & Balteş, 2012; Vuoskoski & Eerola, 2015). Secondly, music could be accompanied by a visual stimulus, designed to emphasise either the structural development of the piece, or narrative and social elements that the music could represent. These two methods appeared plausible for the current study, and it was predicted that for the same piece of music, differences in extra-musical information or visual accompaniment would predictably induce distinct types of chills experience, related to vigilance or social bonding processes.

8.2.2 Subjective Feelings

As consistently presented in the current dissertation, musical chills can be accompanied by a variety of subjective feelings and emotional states, such as being moved, happiness, sadness, excitement, nostalgia and more; these subjective feelings also appear to be a key component in distinguishing between different chills experiences, such as those in the previous chapter labelled warm, cold, and moving chills. In a speculative discussion on some of the emotional qualities associated with vigilance or social bonding chills in **Chapter 3**, it was first suggested that experiences of awe may be closely linked to vigilance processes, whereas being moved and kama muta might be related to social bonding mechanisms; there are additional complexities with these considerations, such as points of crossover across these emotional constructs that have yet to be disentangled or verified. Both emotional responses have further been associated with chills (Benedek & Kaernbach, 2011; Konečni, 2005; Schurtz et al., 2012; Zickfeld et al., 2017). Therefore, it was hypothesised that higher ratings of awe or being moved would be indicative of vigilance or social chills experiences respectively, and that these ratings would be predictably associated with the stimulus manipulations that emphasised structure (vigilance) or narrative (social bonding).

8.2.3 Psychophysiological Response

Across vigilance and social chills with music, there is further evidence, alluded to in **Chapter 3**, to suggest that these chills responses are separable with regards to accompanying psychophysiological activity, with a focus on *skin conductance* and *skin temperature*.

Firstly, skin conductance increases have been reported in relation to aspects linked to vigilance chills, such as expectation and auditory looming. Regarding harmonic violations in music, Steinbeis et al. (2006) found that unexpected chords elicited increases in skin conductance, with the degree of harmonic violation correlating with the amplitude of the skin conductance response (Koelsch et al., 2008); similar results were found in accordance with probabilistic modelling of live concert music listening (Egermann et al., 2013). Comparable findings have been reported for acoustic intensity increases in auditory stimuli, linking the auditory looming phenomenon to increases in skin conductance activity (Bach et al., 2009; 2008; although see Olsen & Stevens, 2013). In studies using music expressive of fear, physiological response patterns are often characterised by increases in skin conductance (Khalfa et al., 2002; Lundqvist et al., 2009), and loudness has been correlated with the measurement (Chuen, Sears & McAdams, 2016; Grewe et al., 2007); in broader psychological work, processes such as the startle reflex, visually or audibly elicited, are accompanied by skin conductance increases (Bradley, Codispoti, Cuthbert & Lang, 2001; Bradley, Lang & Cuthbert, 1993). In contrast, there is less evidence to suggest a certain pattern of skin conductance activity derived from social processes. On the one hand, it might be hypothesised that skin conductance levels would be higher when resulting from fight-or-flight responses (Bradley & Lang, 2000), that are not intuitively a product of social bonding or empathic experiences; on the other hand, numerous studies have contextualised chills in terms of being moved (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2017b), yet continue to document significant peaks in skin conductance corresponding to chills reports. Thus, it was predicted that skin conductance levels would increases in both vigilance and social chills, but that these increases would be higher during vigilance chills.

Secondly, skin temperature has been included in some studies of chills, but results have largely been inconsistent (Craig, 2005; Rickard, 2004; Salimpoor et al., 2009). However, the broader literature suggests that vigilance chills might be accompanied by decreases in skin temperature. For example, fear responses have been linked to drops in skin temperature (Collet et al., 1997; Ekman, Levenson & Friesen, 1983); comparable findings were reported in response to fear music, as opposed to happy music (Baumgartner et al., 2006; Krumhansl, 1997). Crucially, recent research on social closeness, warmth and bonding suggests that social chills might be accompanied by increases in skin temperature. For example, social isolation, elicited in a ball toss paradigm in which computerised players exclude the participant, has been linked to drops in skin temperature (IJzerman et al., 2012); moreover, experiences of social connection or closeness have been associated with increases in physical temperature (Inagaki & Eisenberger, 2013; Inagaki & Human, 2019; Inagaki et al., 2016). Consequently, it was predicted that social chills would be accompanied by higher levels of skin temperature, compared to vigilance chills.

8.2.4 Individual Differences

The final consideration in this concluding experiment was the potential role of individual differences. As highlighted throughout the thesis, emotional experiences elicited by music are largely dependent on the music itself, the listener and the situation, and the interactions between these factors (North & Hargreaves, 2008). When considering the current hypothesis that there exist two separable musical chills experiences, the empathising-systemising distinction in cognitive processing style appears to be an intuitive, logical characteristic of individual listeners to consider. As mentioned in the previous chapter, this approach categorises people into three main brain types: Empathisers, who tend to process events and stimuli at the socio-emotional and empathic level; systemisers, who prefer to process stimuli in terms of rules, patterns, regularities and syntax; and balanced, who present tendencies for both processing types, and reflect much of the neurotypical population (Greenberg, Warrier, Allison & Baron-Cohen, 2018). In the current experiment, the empathising-systemising distinction maps neatly on to vigilance chills and social bonding chills, and has been shown to be linked to differing musical preferences in listeners (Greenberg et al., 2015). Therefore, it was predicted that empathisers will tend to experience more social chills responses, and systemisers will more often report vigilance chills experiences.

8.3 Formal Hypotheses

To summarise the various aspects considered for this final experiment, it is predicted that two types of chills, derived from vigilance or social bonding processes, can be distinguished based on the stimulus manipulations utilised, subjective feelings, physiological activity and individual differences in cognitive processing style. Whilst the empirical predictions for each of these factors have been proposed, the formalised hypotheses for this final study are as follows:

- **H1**: Stimuli with an emphasis on musical structure or narrative will elicit experiences of awe (vigilance chills) and being moved (social chills) respectively
- **H2**: Chills reported within experiences of awe (vigilance chills) will be characterised by higher skin conductance and lower skin temperature; the opposite pattern is predicted for being moved experiences (social chills)
- **H3**: Empathisers will experience tend to report stronger experiences of being moved (social chills) compared to awe (vigilance chills); the opposite is predicted for systemisers.

8.4 Methods

8.4.1 Design

A listening experiment was designed, using four pieces of music. The experiment was split into two blocks of listening. In the first block, participants would listen to two pieces of music, with extra-musical information provided about the piece prior to listening; this information would either emphasise and outline the overall dynamic structure of the piece (*vigilance* condition), or describe a short emotional narrative that would follow the structural development of the music (*social* condition). In the second block, participants would listen to the other two excerpts of music, which were accompanied by a visual animation; this would either be a circle that increased or decreased in size and motion activity when the dynamic intensity of the music increased or decreased (*vigilance* condition), or a moving, short animation that told a bittersweet story (*social* condition). To control for order effects or fatigue, the stimulus presentation order was randomised within each experimental block. However, the experimental block order was kept constant (with extra-musical information followed by visual accompaniment); this was to control for confounding variables such as visual mental imagery that might carry over if experimental blocks were reversed.

The central dependent variables were the frequency of chills reports via button presses, skin conductance and skin temperature during chills reports, and self-reported experiences of awe and being moved. The independent variables were the vigilance or social conditions for each of the four stimuli. Finally, individual differences were assessed in terms of the empathising-systemising distinction. The experiment followed a within-subjects design, where participants listened to all four stimuli, but received one vigilance and social condition in the first block, and one of each in the second block (for a procedural outline, see **Figure 8.1**).

8.4.2 Participants

A total of 44 participants took part in the experiment (mean age = 27.56, SD = 7.44). Of the sample, 17 were male, 27 were female, 36 reported being a student, and 40 reported playing a musical instrument. Participants were recruited through institutional mailing lists, social media (i.e. Facebook, Twitter), and through poster advertisements across the University campus. The final participant sample was selected following a brief pre-screening process, to confirm that all participants had experienced chills with music previously. The sample descriptives are available in **Appendix 5**.

8.4.3 Materials and Measures

Stimuli

The four pieces of music utilised in the current experiment were selected firstly on their reported efficacy to elicit chills in listeners, and secondly their levels of unfamiliarity. The first piece selected was *Glósóli* by Sigur Rós, which is an example of post-rock music with Icelandic lyrics. The piece is 6 minutes 40 seconds in duration, and is an effective elicitor of chills, shown in **Chapter 5** and **Chapter 6**. Overall, the piece follows a simple musical structure, with a basic harmonic progression that changes only in the chorus and towards the end section, in which the music gradually increases in dynamics and textural density, up to a climactic point characterised by a sudden dynamic and textural change.

The second piece selected was *Prayer* by Ernst Bloch, performed on cello with string accompaniment. This piece lasts 5 minutes, has previously been used in music and emotion studies (Juslin et al., 2015; Juslin et al., 2014), and has been reported to elicit chills in users of social media websites such as Quora and YouTube. The piece is carried throughout by a prominent melody performed on the cello, an expressive, voice-like instrument quality; the music follows a simple structure, with a dynamic and textural climax arriving in the final moments of the piece.

The third piece used was the fourth movement of *Pines of Rome* by Ottorino Respighi, a further piece linked to chills through online forums and social media, with an overall structure comparable to Glósóli. The piece lasts 5 minutes 40 seconds and can be split broadly into two sections: The first is comprised of a long, steady increase of dynamic intensity and textural density lasting over two minutes; the second begins with an abrupt large crescendo and dynamic climax, accompanied by a key and pitch chroma change, and change of instrumentation.

The fourth and final piece was a short video game music excerpt from Final Fantasy IX, called *Behind the Door*, composed by Nobuo Uematsu. This excerpt lasts 2 minutes and 5 seconds, and resembles emotional film stimuli often utilised in music and emotion work (Eerola & Vuoskoski, 2011). This music has again been linked to chills through online forums. Written to accompany an animated scene in a video game, the music is cinematic and expressive, with a rhythmic pattern of strings and woodwind in a major key, before turning quiet and moving to the relative minor key, before a final crescendo and dynamic peak in the music; this moment in the music was originally written to synchronise with an on-screen reunion between two characters, a prototypical example that elicits being moved (Wassiliwizky et al., 2015).

Stimulus Manipulations

In the first listening block of the experiment, the pieces Prayer and Pines of Rome were used, and prior to listening were accompanied by one of the following vigilance or social text descriptions:

Prayer - Vigilance Information

The music begins with a first theme played on the cello, before moving into the second theme with more layers of accompaniment; as the dynamics rise and expressive performance continuously increases and develops during the repetition of these themes, the piece then introduces a third interlude section, with a slight change in mood and harmony. Upon leaving this interlude however, the piece climaxes with a large increase in dynamics and pitch range, resulting in the final crescendo of the piece with the return of the initial two themes.

Prayer - Social Information

This music tells the story of a character who awaits a reunion with a loved one from war, the piece opening with a sombre expression of prayers for their safe return. One day however, the character observes two army representatives slowly walk to the front door of the character's house, and upon speaking with them, learns that their loved one was imprisoned during the war, and whilst they remain alive, there is no immediate way to ensure that they return safely. The main character is deeply distressed by the news, but does not accept that the loved one may never return. The main character retreats swiftly back inside, and chooses to continue praying for their loved one's return.

Pines of Rome - Vigilance Information

This piece begins with a long, gradual layering and increase in sound intensity; this long development and increase of sound and instrumentation continues through the first half of the piece, with the slow introduction of a driving percussion rhythm. Towards the end of this build up, the music reaches its dynamic peak, with a prominence of strong brass instruments, and a dramatic arrangement in a minor key. What follows is a very stark, climactic moment of change and contrast, in which the music shifts in key and colour, and progresses with a new melody, accompanied by loud instrumentation and strong driving rhythms. This second half of the piece continues to sustain this theme until a final dynamic climax to mark the end of the music.

Pines of Rome - Social Information

This music tells the story of a character awaiting at their country's border to see if their loved one has survived and returned from the war, with the opening sections of the piece expressing the uncertainty and anxiety of the character in waiting. After a seemingly long time of nervous waiting, as many soldiers are reunited with their families and friends, finally the character sees their loved one in the distance, and begins to cry and sob in relief. Once the character trusts what they see, they run towards their loved one who, upon noticing this, opens their arms to await their reunion and embrace.

For the second block of the experiment, the pieces Glósóli and Behind the Door were used, and were presented alongside a visual animation to participants. To create vigilance conditions for these pieces, an animation was created using Adobe AfterEffects software; for both pieces this was a white circle on a black background, to avoid possible priming of emotion concepts via colour (Curwen, 2018; Ou, Luo, Woodcock & Wright, 2004). This circle increased or decreased in size, thickness and motion in relation to the general dynamic contour throughout the piece; in addition, during the moment of dynamic climax in both pieces, the dimensions of the circle would be displaced and distorted, resulting in a rapidly rotating, large, noise-like circle. These changes were intended to provide a visual emphasis of the structural developments in music linked to vigilance mechanisms. To create social conditions for these two pieces, short animations or film clips were utilised. For Glósóli, an animated film called *The OceanMaker* was used, and for Behind the Door a short excerpt from the film *Storks* was used; both animations were edited to fit the scenes with changes and salient moments in the music. These animations represent positively (reunion after separation) or negatively moving (self-sacrifice for the greater good) scenarios linked to being moved experiences (Wassiliwizky et al., 2015), and these moments are further synchronised with key moments of contrast within the music. Further descriptions and sources for these animations are provided in **Appendix 6**.

Self-Reports

After each stimulus, participants rated their experiences in terms of subjective feeling. These self-reports targeted experiences of awe and being moved, utilised as indicators of vigilance and social chills respectively. For awe, self-report items were extracted from the Awe Experience Scale (AWE-S; Yaden et al., 2019). This instrument was developed, tested for internal consistency, and shown to correlate with existing instruments previously used to indirectly assess awe (e.g. Shiota, Campos & Keltner, 2003). The AWE-S is comprised of a six-factor structure, with three factors deemed most appropriate for the theoretical basis of vigilance chills; these factors were *physical sensations*, *perceived vastness* and *need for accommodation*, principal aspects traditionally related to awe (Keltner & Haidt, 2003; Shiota et al., 2007). In total, 13 items were used from the AWE-S (Likert-type, 1-7), three pertaining to bodily activity and 10 to subjective feelings.

For being moved, self-report scales were taken from the KAMMUS-2 instrument (Zickfeld et al., 2019). This scale has been utilised and validated across different languages and contexts, and consists of five main sub-scales. Of these, three were utilised for the current experiment, which were *physical sensations*, *appraisals* and *motivations*, encapsulating feelings of communion, love and wanting to express social bonding and closeness with others. Physical sensation item selections were motivated by providing a balance across ratings for awe and kama muta, and by evidence suggesting that chills can co-occur with a variety of other sensations (Algoe & Haidt, 2009; Maruskin et al., 2012; Wassiliwizky et al., 2017a) that may indicate meaningful differences in experience (Nummenmaa et al., 2018). In total, 11 items were utilised from the KAMMUS-2 (Likert-type, 1-7), three linked to bodily activity and 8 to subjective feelings.

With regards to individual differences, the hypothesised cognitive processing styles of empathising and systemising were assessed, using both the empathising quotient (EQ; Baron-Cohen & Wheelwright, 2004) and revised systemising quotient

(SQ-R; Wheelwright et al., 2006). The EQ is comprised of 60 statements, containing 20 distractor items that are not scored. For each statement, participants can score a maximum of two points and a minimum of 0, resulting in a possible score range of 0 to 80; higher scores reflect a stronger empathising approach. The SQ-R is an instrument containing 75 statements, with no distractor items included. Like the EQ, the maximum score per statement is two, and the minimum is 0, with a possible total score range of 0 to 150; the higher this total score, the more systemising qualities a person expresses. Across both instruments, participants respond to statements with a strongly agree, agree, disagree or strongly disagree, regarding the extent to which these statements reflect how participants sees themselves.

Physiological Activity

Physiological activity was recorded in the form of skin conductance and skin temperature. Skin conductance data were collected using two electrodes (Ag/AgCL) that were attached to the distal phalanx of the index and middle fingers of the non-dominant hand. Skin conductance was utilised in this experiment for similar reasons as those in **Chapter 5** and **Chapter 6**: collecting skin conductance is a non-invasive procedure, and has been linked to the incidence of chills; an additional, important reason for use is that empirical predictions derived from the vigilance and social chills distinction suggest that different underlying processes may result in a measurable variation in skin conductance amplitude across distinct chills experiences. As an additional measurement, skin temperature data were also collected; this was achieved by attaching a thermistor, in the form of a small wire lined up with the palmar surface of the small finger of the non-dominant hand, with the end of the wire aligned and taped to the fingertip. The collection of skin temperature data was motivated by two factors: Firstly, this measurement procedure is non-invasive and reasonably comfortable, enabling the elicitation of musical chills in experimental conditions; secondly, the theoretical distinction between vigilance and social chills suggests that there may be different patterns of skin temperature response, depending on the chills experienced. Physiological data were sampled at the rate of 32Hz, and all physiological measurements were carried out using the NeXus-10 MKII hardware and BioTrace software.

Chills Measurement

To measure the experience of chills in listeners, participants reported the onset of a perceived chills response in real time by pushing a button. Previous work often utilises physiological activity to validate self-reported chills experiences, by assessing whether the button press is accompanied by significant increases in skin conductance activity (Craig, 2005; Egermann et al., 2011; Grewe et al., 2007); this procedure was also recruited in **Chapter 6**. However, given the aim of investigating distinct types of musical chills experiences, with physiological activity used as a distinguishing feature, the existing validation methods were not replicated, and button presses from participants were mostly retained for analysis. To control for abnormal behaviours in button presses that might influence the sensitive chills frequency measure (e.g. overuse of the button, or accidentally tapping the button twice in quick succession), button presses from a participant were omitted from the analysis if they were within seven seconds of the preceding button press; this length of time was selected based on the average duration of chills experiences from previous work (Craig, 2005), and data from **Chapter 6**.

8.4.4 Procedure

Each participant was tested separately, and assigned to one of two experimental groups; in group one, participants received vigilance conditions for Pines of Rome and Glósóli, and social conditions for Prayer and Behind the Door; for group two, these stimulus and condition combinations were reversed (see **Figure 8.1**). To start, participants familiarised themselves with the experimental procedure and data protection standards, presented in an initial participant information screen; following this, informed consent was obtained. Before the main experiment, participants completed basic demographic questions, whilst electrodes and thermistor were connected to the participant's non-dominant hand. As an important safety and control measure, the experimenter played a short piece of music to participants, representing the maximum level of loudness to be encountered in the experiment; the volume of this music was set between experimenter and participant, aiming for the music to be as loud as possible, but for there not to be any discomfort. Participants could then move through the first block of stimuli in the experiment, providing self-reports after each stimulus, and indicating chills experiences by pushing down the space bar whilst listening or watching. After a short break, participants could then move through the second block of the experiment, with the same procedure as the first. Once the listening experiment had concluded, participants were presented with the EQ and SQ-R instruments. All participants were paid £5 for participation. The experiment was approved by the University Ethics committee, and all data were fully anonymised throughout the collection and analysis procedures; on average, the experiment took

45 minutes to complete.

8.4.5 Data Analysis

All data analysis was performed in R; generalized and non-generalized linear mixed effects models were constructed using the '*lme4*' package (Bates et al., 2015). Following similar statistical procedures of Chapter 6 and Chapter 7, assessing the statistical significance of fixed effects was performed utilising likelihood ratio tests, comparing full mixed effects models with reduced models (i.e. no specified fixed effects). The effect sizes of the models were estimated using marginal R^2 values following calculations from Nakagawa and Schielzeth (2013); these were computed in R using the '*MuMIn*' package (Barton, 2018).

Self-Report Transformations

For EQ and SQ-R instruments, data were scored according to instructions, omitting distractor questions, and following negative or positive scoring structures. For ratings of awe and being moved, responses were averaged for each stimulus, across the 13 scales derived from the AWE-S, and 11 scales derived from the KAMMUS-2. However, as both instruments have recently been developed, it was unclear how rating patterns for both instruments compared; in an early diagnosis, a principal components analysis of the subjective feeling scales reported that both instruments were separable,

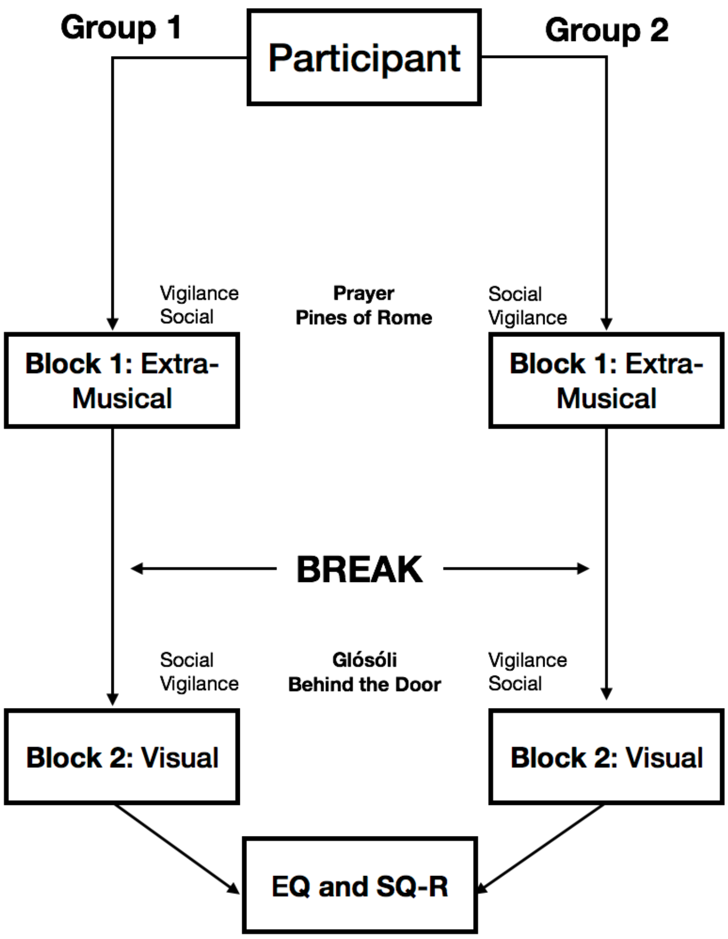

Figure 8.1: Procedural outline of the experiment; stimulus orders within each experimental block were counterbalanced across participants.

yet the distribution of awe scores was consistently higher compared to being moved. As a result, to allow for more intuitive comparisons, scores were normalised across participants, within the two instruments; the same procedure was carried out for the EQ and SQ-R data, given the different raw scoring scales (80 max score for EQ, 150 for SQ-R).

As a final preparatory step, given that all stimuli and conditions may hypothetically elicit both vigilance or social chills responses (Huron, 2006; Margulis, 2017), and that awe and being moved may both be experienced in some scenarios, a continuous *emotional experience* scale was produced for subjective feelings, by subtracting normalised mean being moved ratings from awe ratings for each participant and stimulus. These subsequent ratings followed a normal distribution, and served as the main dependent variable for subjective feeling that more clearly encapsulated and distinguished experiences that resemble awe or being moved from those that are more emotionally balanced. In this scale, negative values indicate a stronger experience of being moved, whilst positive values indicate more intense experiences of awe; scores tending towards zero reflect balanced experiences. These self-reports served as a proxy for characterising and categorising vigilance or social chills experiences. Notably, the same calculation procedure was carried out for empathising-systemising scores, producing a *cognitive style* scale; negative values on this scale indicate strong empathising characteristics, whereas positive values reflect systemising tendencies.

Psychophysiology

Skin conductance and skin temperature data were firstly detrended, as both measurements display a gradual linear decrease over time. Skin conductance data were then pre-processed and analysed in accordance with methods derived and presented previously in **Chapter 5** and **Chapter 6**; both the phasic skin conductance response (SCR) and tonic skin conductance level (SCL) were extracted from the raw data and selected for analysis, using the continuous decomposition analysis method carried out through the 'Ledalab' package developed for MATLAB (Benedek & Kaernbach, 2010). The phasic SCR was selected as an accurate, higher resolution measure of event-related physiological activity, and the tonic SCL was also retained to indicate slower trends in physiological activity possibly linked to chills reports (Boucsein, 2012).

In the current analysis, phasic SCR, tonic SCL and skin temperature were utilised as possible indicators of vigilance or social chills. Following pre-processing and decomposition of the skin conductance signal, all measurements were normalised within each participant to account for individual differences in resting physiological activity (Khalfa et al., 2002). To characterise the chills responses of participants, the 4 second epoch following each button press report of chills was taken, and compared to the 4 second epoch directly preceding the same button press; for all measures, the mean change in signal from pre- to post-button press was utilised for analysis. The pre- to post-button press comparison was preferred over comparisons to a baseline epoch of physiological activity as utilised in **Chapter 6**, given that the focus of comparison was not on validating chills experiences, and that the data may reflect more closely the specific, differing qualities of the chills responses; for example, by comparing to a baseline, some chills may be accompanied by 'increased' skin conductance or temperature, when the button press is accompanied by no such localised change as expected.

Chills Categorisation

To establish relationships between physiological data and chills reports, one strategy was to average across button presses for each participant and each stimulus, and to correlate these measurements with the bipolar *emotional experience* scale aggregated from self-reports of awe and being moved, and the *cognitive style* scale aggregated from the EQ and SQ-R; however, this strategy is sensitive to varying magnitudes or intensities of *emotional experience* and *cognitive style,* which may not be the most appropriate level when considering distinct chills experiences and the complexities of physiological activity. Alternatively, an additional analysis strategy less sensitive to the varying magnitude or intensity of ratings was to categorise self-reported experiences into three prospective chills types: *Vigilance*, *balanced*, and *social chills*. This was achieved by splitting the normally distributed *emotional experience* scale into three equal proportions: scores in the 33rd percentile or lower were judged to reflect experiences of social chills, scores in the 67th percentile or higher were classified as reflecting vigilance chills responses, and all scores in between were assumed to reflect a balanced affective experience (see **Figure 8.2**). From here, physiological data could be compared across the three nominal chills categories. If the vigilance and social stimulus conditions predictably and consistently resulted in awe or being moved experiences respectively, then it was judged that this categorisation of *emotional experience* ratings would be a reliable proxy for characterising different types of chills responses. The same procedure of categorisation was carried out for the *cognitive style* scale, resulting in categories of *systemiser, balanced* and *empathiser*. This categorisation procedure was adapted from similar methodologies in previous work (Greenberg et al., 2018; Wheelwright et al., 2006).

8.5 Results

8.5.1 Descriptive Statistics

The following descriptive statistics consider firstly the frequency of chills reports across stimuli and conditions, and secondly the self-reported subjective feeling data across stimuli and conditions. For an overview of the descriptive data, see **Table 8.1**.

Frequency of Chills Reports

Across the listening experiment, with 44 participants experiencing four stimuli each (total = 176 experiences), a total of 692 chills responses were reported via button presses, suggesting that the stimuli used and participants recruited resulted in an effective paradigm for eliciting chills in an empirical setting. Of the 44 participants, only five reported no chills throughout the experiment. At the level of condition, the social conditions resulted in more chills reports (N = 363) compared to vigilance conditions (N = 331), with the most effective elicitor being the social condition of Glósóli (N = 130). To assess whether the frequency distributions were significantly different across stimuli and conditions, generalized linear mixed effects models

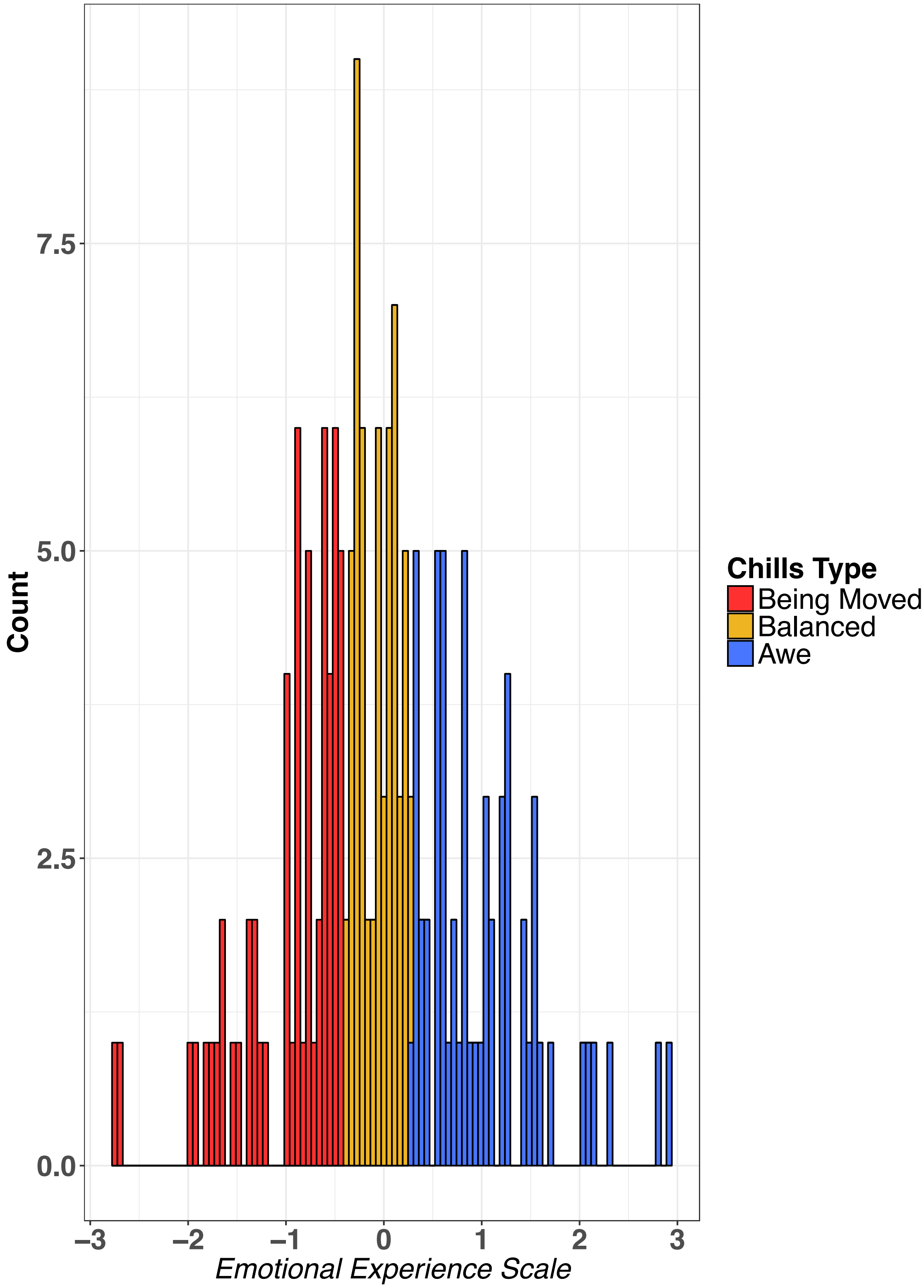

Figure 8.2: Visualisation of the categorisation procedure for chills experiences from the *emotional experience* scores; these categories were separated according to the 33rd and 67th percentile values in the distributions.

were constructed. For positively skewed chills frequency data, models were fit with a Poisson distribution; the dependent variable was chills frequency, fixed effects were vigilance or social stimulus conditions, and individual participants were fitted as a random effect. At the level of vigilance and social conditions, no significant difference was found for chills frequency (z = -1.23, p = .21); at the level of stimulus and condition combinations (total = 8), post-hoc, holm corrected Tukey contrasts suggested that the social condition of Glósóli elicited significantly more chills compared to the vigilance condition of Behind the Door (z = 5.89, p <.0001), the social condition of Pines of Rome (z = -4.30, p = .0004), and the vigilance condition of Prayer (z = -3.46, p = .013). As a final exploration, the level of manipulation type was considered, comparing across extra-musical information or visual accompaniment approaches; no significant differences in chills frequency were found across manipulation type (z = .30, p = .75). These results suggest that chills were elicited similarly across the vigilance and social conditions, and the different manipulation approaches; however, the social condition of Glósóli was most effective, and resulted in significantly more chills reports compared to some other stimuli.

Subjective Feelings

After each stimulus, participants were asked to rate their experiences in relation to awe and being moved, involving both physical activity and subjective feeling components (all with scoring ranges of 1-7). At the level of vigilance and social conditions of the stimuli, raw, mean awe ratings were 2.74 (SD = 0.98) and 2.85 (SD = 1.01) for vigilance and social conditions respectively; for being moved responses, mean ratings were 2.13 (SD = 0.93) and 2.73 (SD = 1.02) for vigilance and social conditions respectively. Notably, whilst raw awe ratings were similar across conditions, being moved ratings appeared to decrease in the vigilance conditions of stimuli. At the level of manipulation type, the mean awe rating for extra-musical information stimuli was 1.86 (SD = 0.98), and for visual accompaniment stimuli was 1.73 (SD = 1.01); for being moved the mean rating for audio-only was 1.45 (SD = 0.98), and for audio-visual was 1.42 (SD = 1.03).

Table 8.1: Descriptive statistics across stimuli and conditions for chills frequency, familiarity (1-5), enjoyment (1-7), intensity (1-7), awe (1-7), being moved (1-7), and the bipolar aggregated *emotional experience* scale.

Condition	Stimulus	Chills (*N*)	Familiarity	Enjoyment	Intensity	Awe	Being Moved	***Emotional Experience***
Vigilance	*Prayer*	80	1.36	5.68	4.86	2.93	2.90	**-0.22**
	Pines	96	1.71	4.61	3.38	2.91	1.69	**0.65**
	Glósóli	105	1.81	4.59	3.13	2.61	1.88	**0.25**
	Door	49	1.40	5.00	3.86	2.62	2.07	**0.01**
Social	*Prayer*	96	1.42	5.42	4.52	2.54	2.58	**-.034**
	Pines	69	1.45	5.27	4.27	3.05	2.61	**0.10**
	Glósóli	130	2.09	5.31	5.00	3.30	2.80	**0.18**
	Door	67	1.40	4.68	4.36	2.49	2.94	**-0.65**

Note: Pines = *Pines of Rome*, Door = *Behind the Door*.

8.5.2 Vigilance and Social Chills

Stimulus Manipulation

To assess the first experimental hypothesis (**H1**), the self-reported subjective feeling data were firstly compared across the level of stimulus manipulation, concerning vigilance and social stimulus conditions. In line with the analysis strategy, the aggregated *emotional experience* scale was utilised, where negative values indicated stronger being moved experiences, and positive values indicated awe. In assessing these values across vigilance or social stimulus conditions and manipulation type with a linear mixed effects model (condition and manipulation type fitted as fixed effects, individual participants fitted as random effects), a significant effect of condition was found ($\beta = .17$, $SE = .06$, $t = 2.58$, $p = .009$), with vigilance conditions resulting in more positive scores, and social conditions leading to more negative scores; no effect of manipulation type was found ($\beta = -.05$, $SE = .06$, $t = -.77$), and no significant interaction between manipulation type and condition was found ($\beta = .02$, $SE = .11$, $t = .23$). These findings support the first hypothesis, mainly that by framing the same musical stimulus with a vigilance or social focus (using extra-musical information or visual accompaniment), stronger experiences of awe and being moved can be elicited respectively. Importantly, *emotional experience* scores now served as a proxy for chills responses reported within the listening experiences.

Psychophysiological Response

To address the second experimental hypothesis (**H2**), namely that vigilance chills are accompanied by higher skin conductance and lower skin temperature levels compared to social chills, physiological activity patterns were first correlated with the *emotional experience* scores, to assess the relationship between skin conductance or temperature with differing degrees of awe and being moved. An average physiological value was calculated across all chills reports with each stimulus, for all participants, and Pearson correlations were carried out between this aggregated data and the experience ratings. Results revealed that tonic skin conductance showed a positive, weak correlation with experience ratings (t = 1.02, df = 64, r = .15), whilst skin temperature showed a negative, weak correlation with experience scores (t = -0.89, df = 73, r = -.18); however, whilst the directions of these relationships were in line with the empirical predictions regarding vigilance and social chills, no correlations were statistically significant.

As an alternative analysis, to accommodate the possibility that physiological activity is not strictly correlated with the magnitude of awe or being moved experiences, physiological activity was compared across three prospective chills types derived from the *emotional experience* scores, namely *vigilance*, *balanced* and *social* types (see **Methods**). For all psychophysiological measures, a linear mixed effects model was constructed (chills type fitted as a fixed effect, with individual participant and stimulus fitted as random effects). Regarding tonic SCL, the model captured significant effects of chills type (x^2 = 269.55, df = 2, p <.001, R^2 = .04); planned, holm-corrected post-hoc comparisons, predicting that SCL would be significantly higher in vigilance chills compared to social chills, suggested that this was the case ($ß$ = -0.13, SE = 0.009, z = 13.78, p <.001). When assessing phasic SCR during chills, a significant effect of chills type was found (x^2 = 49.68, df = 2, p <.001, R^2 = .01); however, in contrast to tonic SCL, phasic SCR was significantly higher in social chills compared to vigilance chills ($ß$ = 0.43, SE = 0.06, z = 6.55, p <.001). Finally, regarding skin temperature, significant effects of chills type were found (x^2 = 149.55, *df* = 2, *p* <.001, R^2 = .02); post-hoc planned comparisons, predicting that skin temperature would be significantly higher in social chills compared to vigilance chills, suggested that this prediction was correct, although this difference was only marginally significant (*ß* = -0.007, *SE* = 0.003, *z* = -2.00, *p* = .044), and should be interpreted with caution.

These results partially support the second experimental hypothesis, with chills reported within stronger experiences of being moved experiences accompanied by higher skin temperature and lower tonic SCL levels when compared to chills reported within stronger awe experiences. Phasic SCR is a notable exception to predictions, although it must be noted that by visualising the average phasic SCR time-series (**Figure 8.3**), there was a substantial peak in activity found in experiences of awe compared to being moved, but this mostly occurred before the reported onset of chills; after the button press, phasic SCR activity appears comparable across vigilance and social chills. Furthermore, the correlational analysis approach suggests that physiological activity is less sensitive to the degree of intensity of an awe or being moved experience. Finally, it is worth noting that whilst significant differences were reported, the estimated effects of chills type on physiological activity, evidenced through both marginal R^2 calculations and standardised beta co-efficients, appear to be small, and there are likely several other factors and aspects that determine physiological response patterns across individuals. The average time-series results are visualised in **Figure 8.3**.

Individual Differences

The final hypothesis (**H3**) concerned the possible role of individual differences, mainly the empathising and systemising cognitive processing styles. It was predicted that systemisers would report stronger awe experiences, and empathisers would report more being moved responses, in turn reflecting the tendency to experience vigilance or social chills with music. Furthermore, it was predicted that systemisers would report more chills in vigilance conditions, with empathisers experiencing more chills in social conditions. To assess links between empathising-systemising and emotion ratings, spearman rank correlations were performed using the overall *cognitive style* scale (see **Methods**), with negative scores indicating stronger empathising tendencies, and positive scores reflecting systemising tendencies. However, no relationship was found between *cognitive style* and *emotional experience* scores (r_s = .06, p = .18). To explore how *cognitive style* affected reported chills experiences in vigilance or social conditions, interaction effects were assessed between stimulus conditions and *cognitive style* on frequency of chills, reported in a general linear mixed effects model with poisson distribution; however, reflecting correlation results, there was no clear interaction between stimulus condition and *cognitive style* scores in determining frequency of reported chills (χ^2 = 0.31, *df* = 2, *p* = .85), indicating no immediate relationship between the empathising-systemising distinction and experiences of vigilance or social chills with music.

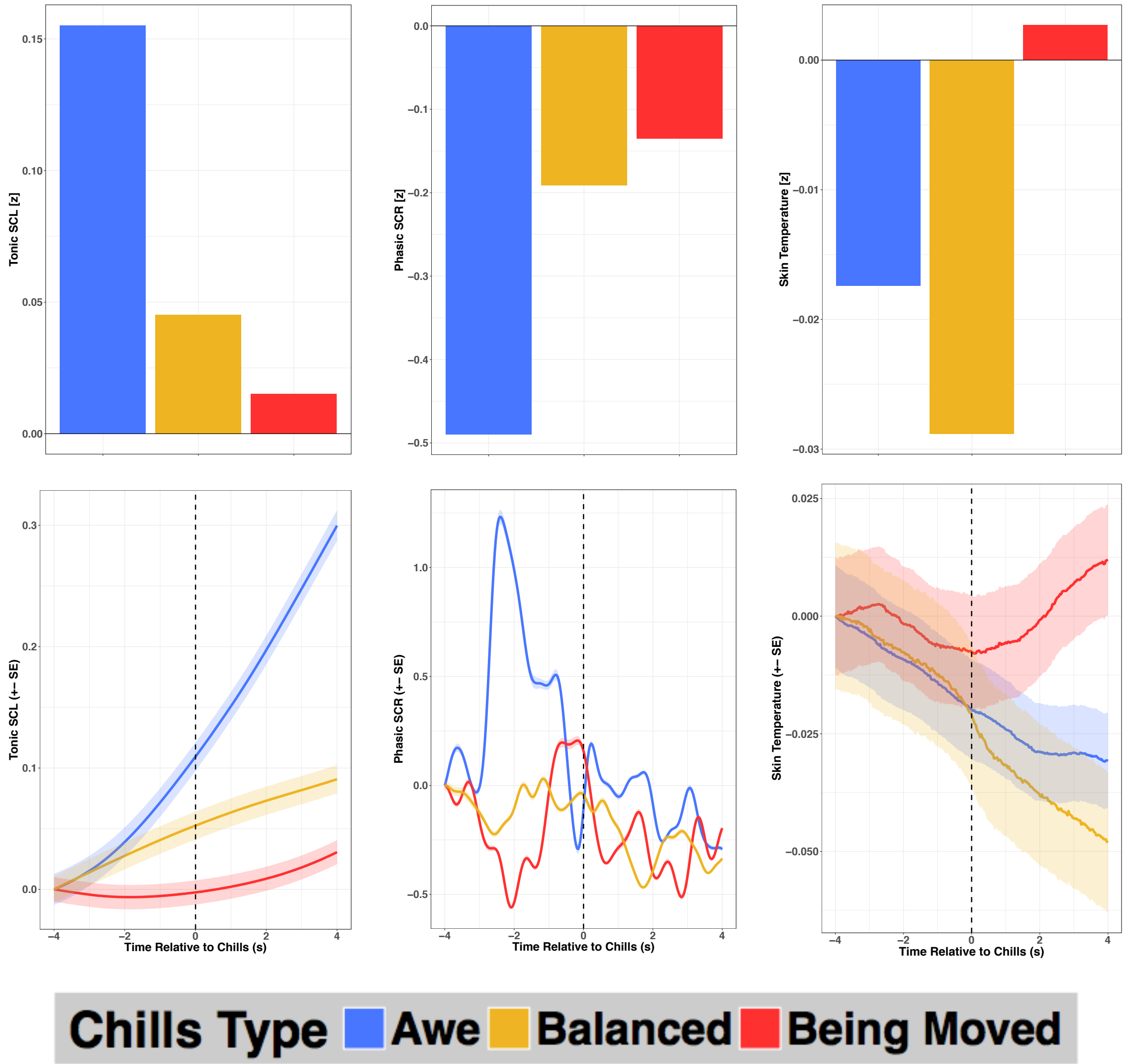

Figure 8.3: Visualisation of mean differences in physiological activity (tonic left, phasic centre, temperature right) across chills types (top row represents means, bottom row represents average time-series activity, ranging from 4 seconds before to 4 seconds after chills reports).

8.6 Discussion

The final experiment of this project aimed to investigate the theoretical distinction between two types of chills with music, namely vigilance and social chills. It was hypothesised that these experiences would be separable at the level of stimulus manipulation, subjective feelings, psychophysiological response and individual differences of the listeners. Evidence suggests that this could be the case: When musical stimuli are paired with extra-musical information or visual accompaniment that emphasises structural development, experiences tend towards awe instead of being moved, whereas information or visual accompaniment emphasising narrative and social components results in stronger being moved states. Also, when categorising subjective feeling reports into three types, either vigilance, balanced or social, it was found that chills within vigilance experiences demonstrate increased tonic skin conductance compared to social those in social experiences, and the opposite was true for skin temperature. However, *cognitive style* scores did not appear to correlate with overall experience scores, suggesting that the type of chills experienced may not be associated with empathising or systemising processing styles. The following discussion addresses the implications of these findings, the limitations of the methods used, and the importance of replication and extension of the present work.

The preliminary evidence provided in this study reaffirms several interpretations made throughout this project regarding musical chills. Firstly, the vigilance and social bonding theories of chills are not adequate, in isolation, to explain the variety of emotional characteristics of the response, and the multitude of eliciting factors or qualities in music; however, this may be due to some chills being psychologically distinct from others, suggesting that the current conceptualisation of chills as a unified indicator of peak pleasure is not sufficiently nuanced, and that the construct may encapsulate numerous, separable psychological phenomena. Secondly, the developing evidence and allusions supporting the distinct musical chills perspective (Levinson, 2006; Maruskin et al., 2012; Panksepp, 1995; Pelowski et al., 2017) has cascading effects on interpreting inconsistencies in the extant literature highlighted in **Chapter 3**, namely at the level of psychophysiological activity and individual differences. For example, whilst skin conductance has been consistently linked to chills, results are considerably varied with regards to skin temperature (Blood & Zatorre, 2001; Rickard, 2004; Salimpoor et al., 2009; Salimpoor et al., 2011), and aspects such as heart rate and respiration rate (Blood & Zatorre, 2001; Salimpoor et al., 2009; Sumpf et al., 2015; Mori & Iwanaga, 2017). Furthermore, contradictory results are found regarding brain activity during chills; Salimpoor et al. (2011) reported increased activity in the nucleus accumbens during chills compared to moments preceding the chill, whereas Wassiliwizky et al. (2017b) found opposite patterns of response. Whilst speculative, the inconsistencies surrounding chills responses may be explained by distinguishing between vigilance and social chills experiences. With regards to individual differences and chills, there are further inconsistencies; openness to experience has been linked to chills (Colver & El-Alayli, 2016; McCrae, 2007; Nusbaum & Silvia, 2011), although Starcke et al. (2019) reported no relationship; moreover, Sumpf et al. (2015) reported correlations between chills and agreeableness, although other research presents null or negative relationships (Colver & El-Alayli, 2016; Maruskin et al., 2012; Nusbaum & Silvia, 2011). Importantly, whilst the present experiment suggested no clear relationship between that individual differences such as empathising or systemising processing styles and different chills experiences, the implication is that earlier inconsistencies across individual differences and chills may be explained by the possibility that studies are assessing different chills experiences, without being able to specify them. Therefore, individual differences need to be explored further at the level of distinct chills experiences, as opposed to a more holistic rate of incidence, as proposed in **Chapter 3** and suggested in the previous chapter.

Limitations

There are several limitations attributed to the current experiment design. Firstly, there is a difficulty in bridging the gap between self-reported emotional experience and individual chills reports from participants. Whilst subjective feelings were utilised as a proxy and index for the categorisation of chills experiences, future research should aim to develop methodologies that more directly assess the moment-to-moment emotional qualities of the chills reported; in this case, continuous measurements of experience may be employed as in **Chapter 5**, although it remains a delicate process to include task demands whilst retaining strong emotional responses in laboratory settings.

Secondly, the current study utilised two different methods of stimulus manipulation, with the visual accompaniment method creating audio-visual stimuli. Discerning the emotional effects of audio, video and interactions between the two is highly complex, and in these instances, there is reduced clarity regarding the effects of music specifically; however, the method was included to maximise and diversify approaches to eliciting vigilance and social chills.

Thirdly, and relatedly, there are possible confounds in terms of how individuals process visual compared to audio stimuli (e.g. Felder & Silverman, 1988); these were not encapsulated by any self-report instruments utilised, and so it is not clear whether some individuals are particularly affected by visual or auditory stimulation. Future work should consider assessing for some of these aspects, or replicating the current experiment with further pieces of music, and focussing one manipulation approach.

Finally, regarding physiological activity, it is important to note that the differences found across chills categories were statistically significant, but small; however, it is possible and intuitive to expect that consistent physiological differences across chills experiences will be small, due to the complexity of these signals and measurements, and the substantial variation inter- and intra-individually (Khalfa et al., 2002), alongside plethora of other factors that can affect responses. Consequently, it is important to interpret statistical significance with care and caution, and it will be crucial to extend and replicate this line of research to further understand the effects of different chills experiences on psychophysiological activity patterns, and to explore other variations that may more reliably indicate distinctions between musical chills responses.

8.7 Summary

To conclude, this final experiment tested a novel hypothesis describing two types of musical chills, labelled vigilance and social chills respectively. Following evidence-based empirical predictions, the study supported the likelihood of differing chills experiences, derived from two underlying theories based on vigilance or social bonding processes. Vigilance chills appear to be characterised by experiences of awe, increased tonic skin conductance levels and decreased skin temperature; in contrast, social chills are linked to experiences of being moved, less pronounced skin conductance increases, and increases in skin temperature. Future research, and the interpretation of existing work, should consider the possibility that not all chills are comparable, and that differences in experience can be predicted and manipulated in experimental settings. Future endeavours should aim to extend and replicate the current study, explore more explicitly the relationships between chills and related states such as tears (Mori & Iwanaga, 2017; Wassiliwizky et al., 2017b) and autonomous sensory meridian response (Kovacevich & Huron, 2019), and develop methods for better understanding the moment-to-moment emotional characteristics of chills experiences.

9. General Discussion

The current research project had three primary aims and questions pertaining to the phenomenon of musical chills, reflecting major limitations in the current literature. Firstly, the dissertation aimed to elucidate the emotional characteristics and qualities of musical chills, a consideration that had rarely been addressed in previous research, thus compartmentalising the response only as a useful indicator of peak hedonic pleasure. Secondly, this project attempted to establish, for the first time, a causal manipulation approach to musical chills, to develop the research agenda beyond correlation designs, and to test existing theories of the phenomenon. The final aim was to investigate and challenge the current conceptualisation of chills as a unitary construct that reflects hedonic experience, by producing evidence of numerous, separable categories of aesthetic chills, distinguished at the levels of underlying psychological mechanisms, subjective feeling, psychophysiological response, and individual differences. In this concluding chapter of the dissertation, the progress towards these aims will be evaluated, and contextualised in terms of existing theories of the chills phenomenon; in addition, insufficiencies of the existing theoretical accounts of chills will be re-addressed. As a central output of the project, a framework of distinct musical chills experiences will also be presented and described; this will be situated in relation to existing literature on the proposed mechanisms of music and emotion, and broader theories of emotion. To conclude the project, a comprehensive research agenda will be outlined in accordance with the proposed framework of musical chills, and the implications for interpreting existing research on the topic will be addressed.

9.1 Project Aims Assessment

9.1.1 Emotional Characteristics of Musical Chills

The first limitation of existing research on musical chills was the restrictive approach of utilising the response as an indicator of peak pleasure or intense emotion. Numerous studies have noted the relationship between chills and neurochemical release and brain region activity linked to pleasure experience and regulation (Blood & Zatorre, 2001; Ferreri et al., 2019; Salimpoor et al., 2011; Wassiliwizky et al., 2017b); moreover, other work has suggested that chills are a useful marker of intense emotion (Gabrielsson, 2011; Rickard, 2004), often accompanied by pronounced increases in sympathetic nervous system activity (Benedek & Kaernbach, 2011; Grewe et al., 2007; Laeng et al., 2016). However, rarely is the chills phenomenon approached or investigated in and of itself, as opposed to using the response to indicate adjacent experiences; as a result, almost no research has attempted to characterise the varying emotional qualities of the response, limiting the associations and connections available to other musical emotions that have been assessed at a broader level (e.g. Zentner et al., 2008).

The first study of this thesis (**Chapter 4**) aimed to address this foundational issue with a qualitative survey approach, asking music listeners basic questions about chills, such as what emotions accompany the response, in what situations they occur, and with what music. This survey was successful in characterising the affective qualities of musical chills, noting that participants often describe the experience as strong or intense, and as being comprised of mixed emotions, such as happiness and sadness. These findings were supported further in the second study of the thesis (**Chapter 5**), in which listening experiences involving chills were rated as more moving and emotionally intense compared to those with no chills reported. Additional differences were described in **Chapter 7** and **Chapter 8**, suggesting that chills can vary in terms of affective valence (see also Maruskin et al., 2012), and be accompanied by experiences of awe or being moved.

It is important to note that whilst mixed, strong emotions were linked to musical chills in the first survey study, there was a wide variety of emotions attributed to the phenomenon. The survey also supported previous work on the topic (Nusbaum et al., 2014), as musical chills were reported to occur in a variety of situations and contexts, sometimes alone at home, sometimes with friends at a live concert, and other times in mundane circumstances such as driving to work or doing housework. Finally, mirroring the notable variety of emotional qualities linked to chills in the survey, an extensive selection of 'chills music' was reported by participants, with over 350 unique pieces reported, with the same piece rarely being described by more than one participant; some exceptions included *O Fortuna* by Carl Orff, *B Minor Mass* by Bach, *Hello* by Adele, and the three pieces utilised in **Chapter 5**, namely *Glósóli* by Sigur Rós, *Jupiter* by Holst, and *Ancestral* by Steven Wilson. Likewise, a striking variation was reported across musical features and characteristics linked to the response; whilst transitions, crescendos, peaks and entrances of voices or instruments supported previous correlational work (Grewe et al., 2007; Panksepp, 1995; Sloboda, 1991), novel data were collected, describing the importance of lyrics for musical chills, and the perception of social concepts and interpersonal interactions within the music. Given a general bias towards classical music in music and emotion research, it is understandable that lyrics, a staple of contemporary popular music, has been underrepresented in relation to chills; these important features, alongside broader aesthetic chills literature, cast doubt on common explanations of chills in music, such as those associated with anticipation and expectancy processes.

This initial qualitative approach to musical chills was important to develop a basis for understanding the affective composition of the phenomenon in a musical context, and to comprehend in more detail the plethora of possible elicitors of the response; these two central outcomes provided an essential foundation for engaging with theories of chills, for developing causal manipulation paradigms crucial to test these theories, and for understanding the psychological construct of chills.

9.1.2 Causal Manipulation of Musical Chills

The second central limitation identified in the current research on musical chills was the lack of causal approaches to the phenomenon. Much of the extant work follows a correlational design, in which participants are asked to report or indicate an experience of chills whilst listening to a piece of music; from here, these reports are temporally mapped on to the corresponding point in the music, and from these regions of interest the structural and psychoacoustic qualities are characterised. These studies have proved valuable, linking chills to numerous structural and psychoacoustic features (Grewe et al., 2007; Guhn et al., 2007; Nagel et al., 2008; Panksepp, 1995; Sloboda, 1991); however, whilst correlational work serves as a platform for causal manipulation approaches, no study has attempted to affect the chills experience by manipulating these structural or psychoacoustic features. This is a crucial restriction on developing an understanding of musical chills, as whilst current theories are largely derived from the correlational evidence, these ideas or hypotheses have yet to be explicitly tested; as a result, even with research spanning a period of almost 40 years (e.g. Ferreri et al., 2019; Goldstein, 1980), there is little known about why chills should be elicited by music.

The second study of this thesis (**Chapter 5**) was developed to address the lack of causal approaches in previous literature, and involved producing and testing a causal manipulation paradigm through a listening experiment. Utilising the chills pieces reported in the first study, three pieces were selected, with each having an identifiable 'chills section'; as this was a novel attempt at causally manipulating chills, the manipulation was carried out at a broad, lower level of resolution, with these chills sections removed from the music to create alternate manipulated versions. By having participants listen to both original and manipulated versions of the three pieces, it was found that chills responses could consistently be suppressed. Also, when comparing across the chills section, the removal section and salient musicological or psychoacoustic control sections, continuous ratings of chills intensity were significantly higher during chill sections; similar results were found for phasic skin conductance, although notably there were no differences between chills and removal sections. This second study was a validation and proof of concept, showing that musical chills can be manipulated at the level of incidence and intensity, and this can be achieved by altering regions of interest in appropriate, unfamiliar musical stimuli.

The causal manipulation approach was taken further in the third study of the thesis (**Chapter 6**), advancing the paradigm by carrying out psychoacoustic manipulations of loudness and spectral brightness; both parameters have been linked to chills in previous research (Grewe et al., 2007; Nagel et al., 2008), and in **Chapter 5** of this project. This study also utilised the foundations, both conceptually and experimentally, established in the critical literature review on chills (**Chapter 3**), to causally test an existing theory of musical chills, what has been labelled throughout as the vigilance theory (Huron, 2006). In this study, the phenomenon of auditory looming was recruited (Ghazanfar et al., 2001; Neuhoff, 1998) as a specific process that might explain links between crescendos, chills and expectancy mechanisms (Juslin, 2013). To target auditory looming mechanisms, *Glósóli* and *Ancestral* were utilised from **Chapter 5**, and in this case participants listened to the chills sections, extended in length to start earlier in the piece, thus providing structural context. Notably, these chills sections involved a key moment of transition (dynamic and textural change, or guitar solo introduction); at these moments, loudness or brightness levels were either gradually increased, decreased or left unchanged. By refining the causal manipulation approach, the results of this study offered, for the first time, partial empirical support for a theory of musical chills, with increased loudness resulting in significantly more chills for Glósóli. Intriguingly, as no effects were found for Ancestral, it was suggested that the underlying musical structure (i.e. a guitar solo) did not inherently afford auditory looming processes, hence there was little built-in to the piece that the manipulations could accentuate or diminish. These complexities regarding musical chills are consistent across this thesis: chills were described in several ways by participants in **Chapter 4**; chills sections of different qualities used in **Chapter 5** appeared to be consistently salient in terms of chills, and were possibly empowered by local musical and structural contexts; and psychoacoustic manipulations in **Chapter 6** may have been highly sensitive to the capacities of the underlying musical structure to engage with various psychological mechanisms linked to chills.

9.1.3 The Psychological Construct of Musical Chills

From the causal manipulation approaches carried out in **Chapter 5** and **Chapter 6**, it appears that, given the right circumstances and underlying musical structures, the vigilance theory of musical chills is plausible; however, it is exactly the need for these specific circumstances, and the complexities highlighted throughout this dissertation, that motivated the development of alternative theories that explain why the causal manipulations were not always consistent, and why numerous musical features are associated with chills, such as lyrics and perceived social interactions, but not intuitively with mechanisms of vigilance. Thus, it was important to consider and investigate the possibility that there are multiple induction routes for musical chills, and that a unified psychological construct does not accurately represent the phenomenon. Assessing the construct of musical chills was thus the third and final aim of the thesis, and was achieved by synthesising the findings from the studies of this project, and existing theoretical considerations and empirical evidence.

The possibility that chills are not a unified construct has been alluded to (Levinson, 2006; Panksepp, 1995; Pelowski et al., 2017), and has received empirical attention from Maruskin et al. (2012). In the current theoretical context extensively established in **Chapter 3**, a similar question arises in relation to vigilance theory and social bonding theory of chills, and whether the resulting chills responses can be meaningfully distinguished based on various factors, such as the elicitors in question, subjective feeling, physiological or bodily response, and individual differences. However, little is known about differences in chills experiences, especially in the current theoretical context; to provide a platform for advancing research into this nuanced aspect of chills, the fourth study of this thesis (**Chapter 7**) explored systematic differences in chills with music, videos, texts and images, and possible effects of individual differences such as trait empathy. By utilising an online forum dedicated to frisson, numerous multimedia items were presented to participants in a web-study, and by assessing distinct patterns of subjective feeling and bodily activity responses in chills experiences, three categories of chills were proposed: *warm* chills (positive valence), *cold* chills (negative valence), and *moving* chills (emotionally intense, predicted by trait empathy). These three chills categories were associated with specific multimedia stimuli; for example, warm chills were linked to videos depicting *shared experiences* and communion, where many people moved, sang or celebrated in unison, whereas cold chills were linked to images depicting scenarios of *empathic concern*, distress, loneliness and comfort given from one to another. The third moving chills category was elicited by most stimuli in the study, but was the only category linked to trait empathy. Importantly, this study presented further evidence of systematic differences across experiences of chills, and developed on emotion concepts such as being moved and kama muta (Fiske et al., 2017; Menninghaus et al., 2015), reflecting distinctions between joyful and sad variations of being moved (Tokaji, 2003; Wassiliwizky et al., 2015), and suggesting that the intensification of communal sharing relations (CSRs) can differ in terms of overall flavour (such as involving shared experiences or empathic concern), and level of occurrence (first-, second- or third-person), resulting in variable experiences. Additionally, alongside the causal study that provided evidence for the vigilance theory of musical chills (**Chapter 6**), this fourth web-study using multimedia items provided strong support for the social bonding theory of chills, and related concepts such as being moved. As highlighted throughout the review in **Chapter 3**, it was essential to consider chills and other aesthetic engagements beyond music, to then advance our understanding of the phenomenon in musical engagements; consequently, a final empirical study could be developed to test vigilance and social bonding ideas in a musical context, given that both had received levels of support across this research project.

In the final study of the current thesis (**Chapter 8**), an attempt was made to distinguish between two theorised types of musical chills, namely *vigilance chills* and *social chills*; these reflected vigilance theory and social bonding theory respectively. To achieve this, *vigilance* and *social* conditions were developed for four pieces of music, using either extra-musical information or visual accompaniment that emphasised the structural development of the music (vigilance condition), or the empathic, narrative aspects that the music might afford (social condition). Numerous empirical predictions were made, derived from the theoretical review from **Chapter 3**, and the previous four studies of the research project; these predictions proposed that vigilance and social chills could be distinguished at the level of stimulus manipulation, subjective feeling, psychophysiology, and individual differences. Most of these predictions were fully realised in the listening experiment: Vigilance conditions resulted in significantly stronger experiences of awe compared to being moved, and the opposite was true for social conditions; also, social chills (chills reported in being moved experiences) were accompanied by increased levels of skin temperature and decreased tonic skin conductance levels when compared to vigilance chills (chills reported in awe experiences), although these differences were small. The final prediction, claiming that vigilance and social chills may be linked to whether the listener is an empathiser or systemiser (Baron-Cohen & Wheelwright, 2004), was not clearly supported; further research is required to explore these possible relationships, for example using more applicable rating instruments, such as the music-specific empathising-systemising tools that are available (Kreutz, Schubert & Mitchell, 2008). The study, an empirical culmination of the current dissertation, was crucial to understanding and establishing a novel research agenda aimed at the qualitative and psychological distinctions across chills experiences with music, and also informed the previous correlational literature linking chills to structural features of music; for example, this final listening experiment suggests that features such as crescendos, whilst intuitively linked to vigilance theories, can also indicate moments of empathic or narrative salience, and with the right context or visual accompaniment might also be associated with social bonding theories, acting as a moment of *contrast* (Burnham, 2000; Graesser et al., 1994). These additional possibilities and complexities will be considered in the concluding remarks of this project.

9.2 Theories of Musical Chills: A Final Evaluation

9.2.1 Addressing Variation

In the extant research on the chills phenomenon across various aesthetic engagements, and in the five studies that comprise the current thesis, there is an expanding array of evidence to suggest that researchers have been approaching and conceptualising chills incorrectly. In turn, this suggests that a novel theoretical approach to chills may need to be developed. Importantly, for a new theoretical perspective to be effective, it must consider and encapsulate the *variation* found across four levels in chills research throughout this work; these may be labelled *stimulus type and emotional experience, eliciting features of stimuli, psychophysiological and bodily response,* and *individual differences*.

Stimulus Type and Emotional Experience

Firstly, although chills have received extensive attention in relation to music listening (Harrison & Loui, 2014), chills can occur across a variety of circumstances, such as in response to certain sounds (Halpern et al., 1986), moments of physical contact (Goldstein, 1980; Grewe et al., 2010), films (Wassiliwizky et al., 2015), poetry (Wassiliwizky et al., 2017b), images (Grewe et al., 2010) and religious communal contexts (Inbody, 2015). Alongside this, there is additional variation within the music domain, in terms of what pieces elicit chills effectively in different listeners, as highlighted in the first study of this project, and other work in which chills pieces are nominated by participants (e.g. Salimpoor et al., 2009; Starcke et al., 2019). Correspondingly, there is also significant variation in the emotional qualities of chills experienced with music and multimedia, as demonstrated in **Chapter 4** and **Chapter 7** of this dissertation; chills with music are described as moving, intense, sad, joyous, exhilarating, nostalgic, bittersweet and mixed; also, depending on the images, music videos or texts being engaged with, chills can be experiences of positive or negative valence. Importantly however, the hedonic sensations are assumed to be separable in these cases from the emotional descriptions (Juslin & Sloboda, 2010b), and even the negative cold chills experiences from **Chapter 7** are anticipated to result in some levels of pleasure, and that some people would pursue these experiences. This emotional variation has also been considered and supported by previous research (Grewe et al., 2010; Halpern et al., 1986; Maruskin et al., 2012; Wassiliwizky et al., 2017a). Any theory, framework or explanation of how chills are elicited needs to address variations at the level of *stimulus type and emotional experience*.

Eliciting Features of Stimuli

Secondly, in the case of musical chills, there is a high level of variation with regards to structural and psychoacoustic features that have been associated with the response. Structural features linked to chills include sudden dynamic or textural changes (Sloboda, 1991), crescendos (Panksepp, 1995), entrances of new voices or instruments (Grewe et al., 2007), solo and accompaniment interactions (Guhn et al., 2007), and new or unprepared harmonies (Sloboda, 1991); regarding psychoacoustic parameters, chills were also correlated with loudness and auditory roughness (Nagel et al., 2008), and negative 'chilling' sounds were linked to frequencies within the range of 3kHz and 4kHz (Halpern et al., 1986). Across the studies in the current dissertation, further features and aspects of music were associated with chills, such as lyrics, the human voice, perceiving social interaction and union in music, a famous string theme, a virtuosic guitar solo, and spectral brightness.

Extending beyond music, chills have been linked to certain features or characteristics of film, such as scenes depicting mixed emotional scenarios, with either a positive foreground and negative background, or vice-versa (Wassiliwizky et al., 2015); additionally, audio clips from films linked to chills were often characterised in terms of emotional social interactions between characters, such as departures and farewells (Benedek & Kaernbach, 2011). Aspects of poetry linked to chills were prosocial, communicative cues such as interactions between lovers (Wassiliwizky et al., 2017b). In **Chapter 7**, chills were experienced when watching moments of *shared experience* across crowds of people, and with images depicting tragic circumstances that invited *empathic concern*. Theories or explanations as to how chills occur in these circumstances need to adequately encapsulate variations at the level of *eliciting features of stimuli*.

Psychophysiological and Bodily Response

Thirdly, the existing research on chills appears to demonstrate variation or inconsistency with regards to the accompanying patterns of psychophysiological activity and reported bodily response. A standard paradigm utilised in existing research has been to employ skin conductance as an indicator of chills (Craig, 2005; Egermann et al., 2011; Grewe et al., 2007); however, Rickard (2004) reported little correlation between skin conductance and the chills response, and not every report of chills is accompanied by a significant increase in skin conductance, as exemplified by removing chills reports that do not demonstrate this expected increase (e.g., approximately 27% removal in Grewe et al., 2007; approximately 39% removal in **Chapter 6**). Additionally, skin conductance appears to show differing behaviours depending on whether self-reports of chills are considered, in contrast to objective observations of piloerection; through stimulus repetition, skin conductance shows a habituation effect in self-reported chills, but a sensitisation effect during piloerection (Wassiliwizky et al., 2017b). Moreover, skin conductance may differ during chills depending on whether the music being listened to is participant-selected or experimenter-selected (Mori & Iwanaga, 2014). Some other psychophysiological responses have been considered in relation to chills; to echo **Chapter 3**, heart rate appears to show inconsistent patterns of behaviour in relation to chills (Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Guhn et al., 2007; Salimpoor et al., 2009), also depending on whether the chills are evidenced by self-report or piloerection

(Sumpf et al., 2015); similar conclusions can be made regarding skin temperature (Craig, 2005; Salimpoor et al., 2009). Concerning the goosebumps response, it must further be noted that not all reports of chills are accompanied by visible goosebumps (Benedek & Kaernbach, 2011; Craig, 2005; Wassiliwizky et al., 2017b).

With regards to self-reported bodily activity, there is comparable variation in the sensations reported by participants in relation to chills experiences. For example, Craig (2005) noted that chills can be localised in different areas of the body, such as arms, hands, neck and the spine. Algoe and Haidt (2009) noted that chills can be accompanied by sensations of warmth in the chest. More recently, Mori and Iwanaga (2017) suggested that chills and tears may reflect two separable peak emotional experiences; on the other hand, Wassiliwizky et al. (2017a) presented evidence for the co-occurrence of chills and tears, resulting in increased levels of emotional intensity. Pertinent to this, it is worth noting that Sloboda (1991) found a similar association between sudden dynamic or textural changes and tears, alongside shivers down the spine. In **Chapter 7** of this dissertation, significant variation was found in the bodily sensations reported alongside chills; warm chills were linked to smiling and feelings of warmth, cold chills were associated with frowning and feelings of coldness, whereas moving chills were linked to feeling a lump in the throat and tears; some of these bodily responses were also described in relation to musical chills experiences reported by participants in the first study of this project. Finally, when considering the conceptually adjacent autonomous sensory meridian response (ASMR), sensations appear to be similar, but distinct from prototypical markers of chills, instead focussing on elusive tingling sensations often starting from the scalp and spreading across the body (Barrett & Davis, 2015). Frameworks or theories of the chills phenomenon thus need to sufficiently accommodate variations at the level of *psychophysiological and bodily responses*.

Individual Differences

Finally, there is the pervasive issue of inconsistency of chills experiences across individuals, and within the same individual in different circumstances or at different times. As recorded in previous work, and in the current dissertation, chills appear to be quite rare experiences; they are difficult to elicit across all participants through empirical approaches, and it is estimated that roughly 50% of the population may not experience chills with music (Huron & Margulis, 2010), although no prevalence study has been carried out. More crucially however, is the lack of predictable stimulus-response patterns observed across the correlational research; for example, Panksepp (1995) presented two pieces of music effective at eliciting chills generally, one of which showed notable convergence of chills reports at a moment of sudden dynamic increase, and the other showing several points of converging chills reports that did not correspond to salient events in the musical structure. Grewe et al. (2007) carried out a case study of a piece by Bach, portraying inter-individual differences chills reports related to varying musical structures; Guhn et al. (2007) identified chills passages across three music excerpts, but a subsequent experiment showed that whilst chills were reported during these passages, for some excerpts up to 59% of participants reported chills in other moments of the music. In **Chapter 5** of this dissertation, a similar approach was taken in identifying chills sections in three pieces of music, where most chills appeared to occur; however, there were exceptions, particularly in the case of *Jupiter* by Gustav Holst. Moreover, whilst **Chapter 6** utilised button presses to offer support for the vigilance theory of musical chills, a descriptive assessment of the distribution of button presses noted that participants showed notable variation in terms of when chills were experienced during the excerpts.

Besides the differences and inconsistencies related to correlations between musical structure and chills, there is also the importance of individual differences, at the level of personality traits, familiarity, repeated exposure, and cognitive processing styles. Chills have been linked to openness to experience (Colver & El-Alayli, 2016; McCrae, 2007; Nusbaum & Silvia, 2011; see Starcke et al., 2019 for null results), reward sensitivity (Mori & Iwanaga, 2015), and lower sensation seeking scores (Grewe et al., 2007); in the present project, the chills and openness to experience association was supported (**Chapter 4**), the chills and reward sensitivity link was not supported (**Chapter 6**), and certain types of chills were associated with higher levels of trait empathy (**Chapter 7**). The current project partially reflects inconsistencies regarding personality, highlighted in the previous chapter and **Chapter 3**. There have also been suggestions that experiences of chills may differ depending on gender (Panksepp, 1995); this has rarely been explored, although it must be noted that the fourth study (**Chapter 7**) found no effect of gender on the overall frequency of reported chills. Finally, there is the potential issue of familiarity and repeated exposure effects. Across the musical chills literature, there is no agreement on what role familiarity with the music might play; some studies note that self-selected music is more effective than experimenter-selected music (Laeng et al., 2016; Rickard, 2004; Salimpoor et al., 2011; Salimpoor et al., 2009), but in contrast other work suggests that familiarity does not affect the incidence of chills (Benedek & Kaernbach, 2011; Colver & El-Alayli, 2016; Grewe et al., 2009). In the current dissertation, the effects of familiarity were either absent or unclear; a pertinent example is **Chapter 5**, in which *Jupiter* resulted in less consistent results in terms of skin conductance and continuous chills measurements, which may have been due to high levels of familiarity introducing confounding, extra-musical variables such as episodic memory or evaluative conditioning (Juslin & Västfjäll, 2008). Repeated exposure is another factor rarely accommodated in musical chills research; one exception is an apparent habituation effect on chills, found in one participant with the same piece of music over seven days (Grewe et al., 2007). As highlighted earlier, there was also a habituation of chills reports with repeated-exposure to poetry stimuli, but a sensitisation of goosebumps (Wassiliwizky et al., 2017a). Proposed theories and explanations of how music can elicit chills should also consider variations at the level of *individual differences*.

9.2.2 Theoretical Insufficiencies

In the context of these summaries regarding the chills literature and current dissertation, and the stated requirements for an effective theoretical approach to the phenomenon, it is important to assess existing, main theories of the chills phenomenon, in terms of their explanatory power, and prevailing inadequacies.

Vigilance Theory

Starting with the vigilance theory of chills, as highlighted in **Chapter 3**, the mechanisms of reflex, anticipation and expectation play an intuitive role in eliciting some chills responses (Huron, 2006), by engaging the threat-signalling, fight-or-flight functionality of goosebumps (Darwin, 1872). Thus, vigilance theory has immediate explanatory power with regards to the previous correlational literature on musical chills, linking the phenomenon to dynamic or textural changes, unprepared harmonies, and other structural transitions. In addition, the theory has received partial, empirical support in the current research project, with **Chapter 6** manipulating psychoacoustic parameters in the context of auditory looming processes (Ghazanfar et al., 2002).

However, the theory fails to explain the significant variety of stimuli that might elicit chills, or why the psychoacoustic manipulations in **Chapter 6** worked for only one piece. For example, whilst vigilance processes encapsulate some structural and psychoacoustic features linked to musical chills, this is not the case when considering chills across other domains or sensory modalities, such as physical contact, films, images and poetry; in other words, there is no immediate, intuitive explanation that might associate film or poetry with vigilance mechanisms, although the horror genre is an area of potential in this regard (see Gordon et al., 2016). Moreover, there are limitations within the context of music regarding specific features linked to chills; vigilance theory struggles to adequately accommodate the proposed importance of lyrics, the human voice, and perceived moments of social union or interaction in music, as highlighted **Chapter 4**. There is also a lack of explanatory power when assessing the emotional diversity of chills experiences, which can be intense, exhilarating, highly pleasurable, positively or negatively valenced, moving, bittersweet, melancholic and nostalgic. A possible emotional state proposed for chills elicited through vigilance processes was awe, which appeared to correspond well to stimulus manipulations aimed at emphasising vigilance chills in **Chapter 8**. However, vigilance theory does not easily accommodate bittersweet, moving, melancholic experiences; instead, these emotional outcomes may be better explained by alternative theories.

With regards to psychophysiological and bodily responses, the vigilance theory is well-situated and intuitive, given the reported correspondence between sympathetic nervous system activity and chills experiences (Craig, 2005; Grewe et al., 2007; Laeng et al., 2016), indicative of the fight-or-flight response. Furthermore, the experience of tears has been linked to awe (Cotter, Silvia & Fayn, 2018), and can co-occur with chills (Wassiliwizky et al., 2017a); however, tears have also been associated with being moved, an emotional outcome that, although not fully distinguishable from awe (Konečni, 2005), is not well explained by vigilance processes. Finally, there are some puzzling patterns of results regarding individual differences, that do not fully align with the vigilance theory of chills. An immediate example is the inter- and intra-individual inconsistencies of the chills response; if vigilance, and possibly fear, were central underlying mechanisms for all chills experiences, then a more tangible and predictable stimulus-response pattern might be expected, given the adaptive value of these processes. This is not the case, and whilst there may be some threshold or individual variation regarding vigilance across a neurotypical population, this lack of predictability is a prominent limitation of vigilance theory. Concordantly, familiarity may be a confound in this context, given the role of expectations and anticipations being violated, although effects remain unclear; whilst it is intuitive to suggest that increased familiarity should reduce vigilance responses, Huron and Margulis (2010) suggest that schematic, syntax-driven expectations are resistant to veridical expectations based on explicit knowledge of a specific piece (see Schubert & Pearce, 2016).

Social Bonding Theory

Resulting from the limitations inherent in the vigilance theory of chills, a second approach has been formalised in the current dissertation, labelled the social bonding theory. In contrast to fear and vigilance mechanisms that correspond to the threat-signalling and fight-or-flight functions of goosebumps, social bonding theory places an emphasis on possible interconnections between thermoregulatory and socio-emotional processes in the brain (Inagaki & Eisenberger, 2013; Panksepp, 1998; Panksepp & Bernatzky, 2002); in this context, some emotional, empathic and social experiences may result in a crosstalk and spreading of activation into thermoregulatory systems, resulting in an artefactual goosebumps response. The origins of this proposed coupling of social and thermoregulatory processing are unclear, but one explanation has described the concept of social thermoregulation (IJzerman et al., 2015), in which, through sharing body heat with others to overcome homeostatic inefficiencies in core body temperature regulation, social intimacy and proximity co-evolved with, and became inseparable from, thermoregulation. A proposed underlying mechanism of this process is the sudden intensification of CSRs (Fiske et al., 2017), which might be described as a sudden sense of equivalence, union or identification with another person, entity or concept. Like vigilance theory, social bonding has been supported in the current dissertation, with chills being elicited by stimuli expressing and evoking empathic concern or shared experiences in **Chapter 7**; furthermore, for the first time, some chills experiences were associated with trait empathy in participants.

Crucially however, social bonding theory carries explanatory power particularly in the numerous circumstances in which vigilance theory is less applicable. For example, social bonding theory helps to explain the importance of lyrics, the human voice, super-expressive guitar solos (Juslin, 2001), famous string themes, and social aspects of music in relation to chills, such as perceptions of union. Additionally, this theory is more immediately intuitive in relation to films and poetry, especially considering that chills have been connected to prosocial cues in film audio clips and poetry (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2017b), and moving, mixed scenarios in film clips (Wassiliwizky et al., 2015); also, continuous ratings of goosebumps have been found to correlate with ratings of social closeness and warmth in response to moving film clips (Schubert et al., 2018). A possible emotional state linked to social chills is being moved (Menninghaus et al., 2015), conceptualised more broadly as kama muta elsewhere (Fiske et al., 2017); this broader concept may encapsulate mixed, bittersweet feelings such as nostalgia and melancholy, all of which were reported as affective qualities of some musical chills in **Chapter 4**.

Regarding psychophysiological and bodily responses, the social bonding theory has some explanatory power, but is at odds with some of the prevailing literature; for example, there is no immediate reason to anticipate a high arousal, sympathetic nervous system response (such as skin conductance or pupil dilation) resulting from social or empathic processes. In contrast however, there is evidence to suggest that these social chills might be accompanied by increases in skin temperature (IJzerman et al., 2012; Inagaki & Eisenberger, 2013; Inagaki & Human, 2019; Inagaki et al., 2016), especially in comparison to other experiences, such as those with foundations of fear and vigilance. Chills can be accompanied by other bodily activities, such as feeling a lump in the throat, warmth in the chest, and tears (Algoe & Haidt, 2009; Wassiliwizky et al., 2017a); as mentioned, tears may reflect awe and being moved states, but social bonding theory might better accommodate the other bodily sensations, that have no clear relationship with fear, vigilance and the fight-or-flight response.

Finally, in the context of individual differences, social bonding theory helps to elucidate the interconnections between chills, being moved and trait empathy. Trait empathy and being moved are associated in pleasurable experiences of sad music (Eerola et al., 2016; Vuoskoski et al., 2017), and chills have in turn been associated with being moved (Benedek & Kaernbach, 2011; Menninghaus et al., 2015; Wassiliwizky et al., 2015); the missing piece of these correlations was preliminarily assessed in the current research project, with links found between trait empathy and some chills experiences in **Chapter 7**. In comparison to vigilance perspectives, social bonding theory may in fact predict a level of inconsistency across and within individuals; given the role of social and emotional triggers, and perceived intensification of CSRs, there may be substantial variations depending on a person's background, culture, identity and more. Vigilance mechanisms might instead be more independent of these factors, although variations likely remain, such as cultural differences in syntax processing for example (Balkwill & Thompson, 1999). Regarding familiarity, as effects remain unclear it is difficult to relatively assess social bonding theory; however, there is reason to suspect that familiar music would carry more extra-musical connotations and effects, particularly those associated with social relationships such as episodic memory (Janata et al., 2007; Juslin, 2013).

9.3 Distinct Musical Chills Framework

The central conclusion from the current dissertation, in conjunction with existing research on aesthetic chills, is that the two prominent theories of vigilance and social bonding not only fail to offer satisfactory levels of explanation in isolation, but in fact they appear to complement each other across numerous levels, such that where one perspective struggles to explain the musical chills phenomenon, the other provides an alternative solution. This was hypothesised in the review of the chills literature in **Chapter 3**, and further predictions were made regarding systematic differences across the chills experiences, based on these two theories. The final study of this project offered preliminary evidence that two types of musical chills, one characterised by vigilance, the other by social bonding, can be distinguished at the level of stimulus manipulations, subjective feeling and psychophysiological response. Based on this data, and the extensive, novel theoretical considerations formally developed throughout this dissertation, the central and final contribution of this thesis is to propose a novel *distinct musical chills framework* of listening engagements, to address important levels of variation across existing research, and to aid understanding and further investigations into the phenomenon. This framework is comprised of three main levels: The first encapsulates the interactions and broad roles of the *music, listener and context* that determine the base likelihood of experiencing vigilance or social chills; the second denotes the *underlying psychological mechanisms* involved in different chills experiences; the third and final level characterises vigilance and social chills experiences in terms of *response, organisation and evaluation*, referring to subjective feelings and physiological response that characterise either vigilance or social chills, the speculative organisation of these components, and the role of aesthetic judgments (Juslin, 2013). This framework is schematically presented in **Figure 9.1**, and what follows is a thorough description of the numerous proposed levels and components.

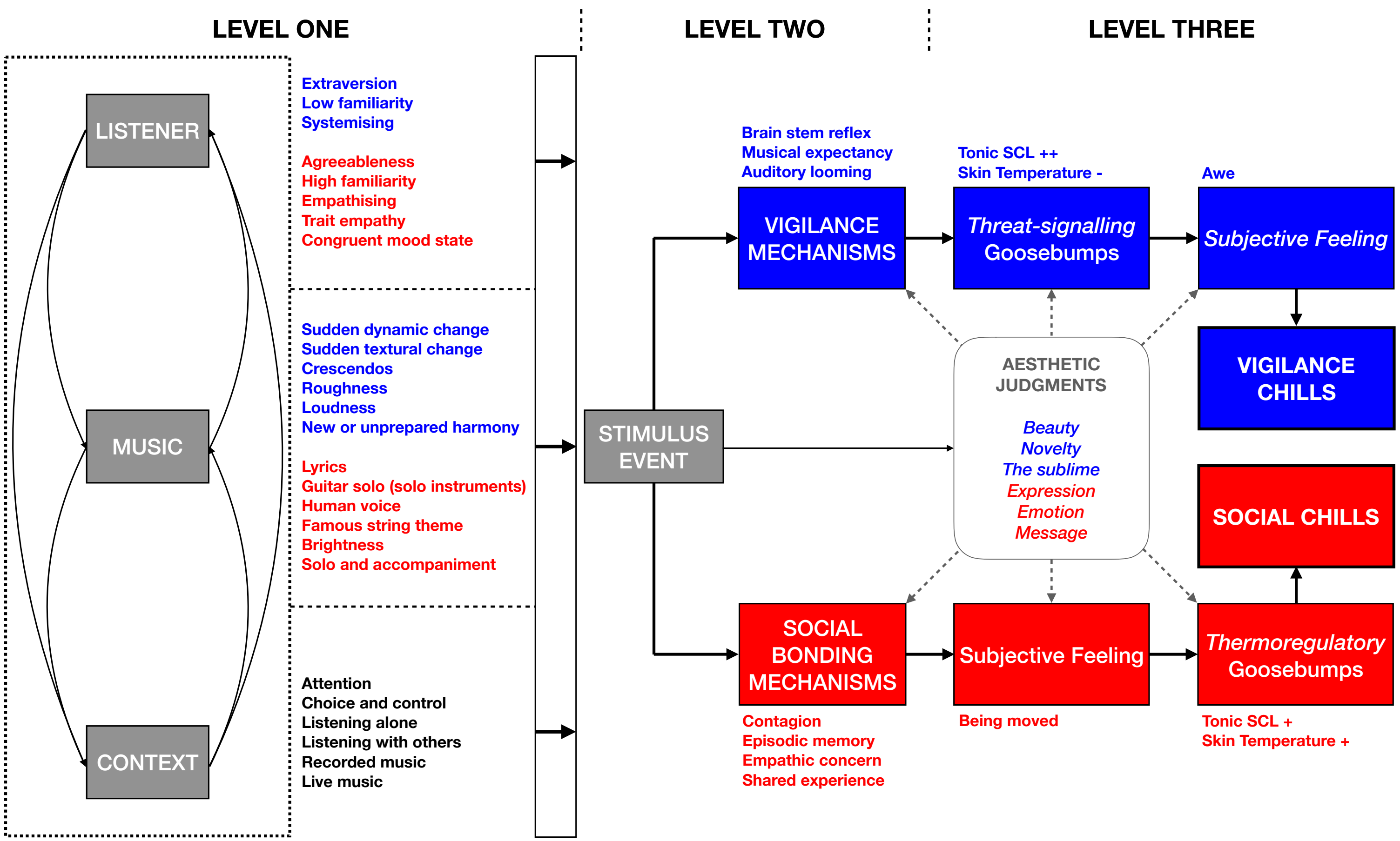

Figure 9.1: A visualisation of the *distinct musical chills framework.* Blue text and boxes indicate predictors and processes of *vigilance chills*, whereas those in red indicate *social chills*.

9.3.1 Level One: Music, Listener and Context

Music

The first component of level one in the framework is comprised of the music being listened to. Considering the extant evidence, it is ambitiously proposed that most any piece of music has the capacity of eliciting chills in some listeners, under certain circumstances; this is particularly the case when considering the complex, multiple interactions between the characteristics of the music, the qualities of the individual listener, and the prevailing listening context, such as listening alone or with others (Egermann et al., 2011), or experiencing live performed music (Lamont, 2011). Furthermore, it is assumed that music from any culture might have the capacity to elicit chills in some listeners (Beier, 2019), regardless of their experience or previous engagement with the music. However, whilst broadly stating that any music listening engagement can potentially involve chills, there are a certain set of structural characteristics and psychoacoustic qualities in music, derived from existing correlational and causal research, that may have a privileged position in terms of their efficacy to elicit the response; these features include those highlighted throughout the current dissertation, such as sudden dynamic and textural changes, crescendos, unprepared harmonies, loudness, spectral brightness, auditory roughness, new voices or instruments, solo instrumental performances (e.g. guitar solo), the human voice, lyrics, and solo and accompaniment interactions. Crucially, the distinction between two types of chills is established at this first level, with the qualities of the elicitor determining a start point for affording different processes linked to vigilance or social bonding. The framework posits that sudden dynamic or textural changes, unprepared harmonies, crescendos and auditory roughness are well suited to engage fear, attention and vigilance processes in a listener; in contrast, social bonding and empathic processes may be engaged effectively by features such as lyrics, the human voice, and moments of solo instrumentation. The underlying mechanisms proposed for these relationships will be discussed at the second level of the framework; these separable processes are the basis for distinguishing between types of chills at each of the following levels of the proposed framework.

Listener

The second component of level one concerns the listener, or more directly the individual differences and variations across listeners. These may be stable, long-term characteristics such as individual traits and familiarity, short-term fluctuating aspects such as prevailing mood state, and a plethora of other extra-musical aspects such as memories and associations.

Firstly, there are individual traits to consider. In the context of personality traits, these mainly include openness to experience, and possibly other traits such as agreeableness, extraversion, neuroticism, reward sensitivity and sensation seeking; a further variable to consider is trait empathy. Finally, there is the potential application of the theorised empathising-systemising distinction (Baron-Cohen & Wheelwright, 2004; Greenberg et al., 2018; Wheelwright et al., 2006); this proposed distinction in preferred cognitive processing styles reflects the two prevailing theories of chills, with systemisers being linked to vigilance, and empathisers more to social bonding. Given the theoretical foundations, empathising and systemising differences were assessed in **Chapter 8**, in relation to vigilance and social chills with music. Although no correlations were found between these processing styles and the type of chills experience, this may be a result of underpowered measurements, or the more immediate fact that in a neurotypical population, most listeners would demonstrate a pronounced balance between cognitive processing styles (Greenberg et al., 2018). Despite these results, the empathising-systemising distinction carries value for theoretical developments of chills, and may be a precedent for further assessing experiences of chills across specialised populations, of which one notable example may be listeners who have been diagnosed with autism spectrum disorder (ASD). Whilst there is striking variation across people with ASD (Nuske, Vivanti & Dissanayake, 2013), comparable to a typically developing population, common aspects include social and interpersonal communication issues (Bird & Cook, 2013); moreover, people with ASD are often characterised as strong systemisers, as opposed to empathisers (Greenberg et al., 2018). Although recent work has shown that listeners with ASD, when compared to typically developing populations, have similar motivations for listening and similar experiences with music (Allen, Davis & Hill, 2013; Allen, Hill & Heaton, 2009), it might be an informative development to explore the quality of chills responses reported in ASD listeners.

Secondly, there is likely an important role of familiarity in musical chills experiences. Familiarity is an interesting factor that has been considered several times in musical chills research with diverging evidence regarding its effects (Benedek & Kaernbach, 2011; Grewe et al., 2009; Laeng et al., 2016; Nusbaum et al., 2014; Rickard, 2004; Salimpoor et al., 2009; 2011). Currently however, no study has attempted to explicitly address effects of familiarity on musical chills. Throughout the current research project, it has been shown that chills can be elicited using unfamiliar music, and this was often a methodological necessity, to control for extra-musical confounding variables when causally manipulating structural or psychoacoustic elements of the stimuli. However, following the same perspective, it is plausible to suggest that familiarity has a determining role in the type of chills that might be experienced with music; on the one hand, unfamiliar music may result in higher levels of attention to the structural and syntactical development of the music, an aspect linked to vigilance processes; on the other hand, familiar music may evoke a variety of experiences, recollections or processes with prominent social and empathic underpinnings, such as memories and associations (Juslin & Västfjäll, 2008), resulting in social chills. This effect of familiarity may further explain inconsistencies in the existing literature, given that the musical chills response might be psychologically distinct each time it is investigated; familiarity may play a key role for some chills, but not for others. The precise function of familiarity in musical chills will require further elucidation, particularly given the complexities of familiarity across different levels of resolution (i.e. with the specific piece, or with style and genre).

Thirdly, there are additional, important short-term variations to consider in the context of musical chills, such as prevailing mood state. Across previous research and the current project, the interactions between existing mood and chills experiences with music have rarely been investigated; despite this, there is some adjacent evidence to suggest that mood might have an effect. For example, chills with music have been associated with feeling one with the music (Laeng et al., 2016), and the first study of this project found that musical chills were accompanied by feelings of being understood or comforted by music, and relating to the music. Notably, these feelings are common motivations for engaging with music (Saarikallio et al., 2018). Music also appears to be able to console or comfort listeners (Hanser, ter Bogt, van den Tol, Mark & Vingerhoets, 2016; Saarikallio & Erkkilä, 2007; Schafer et al., 2013; ter Bogt, Doornwaard, Pastore & van den Eijnden, 2017). Moreover, some listeners engage with sad music to reduce loneliness and justify one's own feelings (Eerola & Peltola, 2016), and to empathise with sadness as if it were another individual (Taruffi & Koelsch, 2014). Importantly, listeners have reported listening to sad music to feel understood when their prevailing mood is negative (Lee, Andrade & Palmer, 2013); furthermore, listeners who are sad have been found to avoid listening to happy music (Taylor & Friedman, 2015). The important aspect here, also in relation to chills, is mood congruence, and its potential role in affording experiences of connection, feeling understood, and being comforted or consoled by music. In these instances, sad listeners may listen to sad music to feel social connections, bonding and empathy, potentially resulting in intensified CSRs, and in turn social chills experiences.

Finally, there are numerous extra-musical aspects to consider. An immediate example is episodic or autobiographical memories with music. Janata et al. (2007) documented the link between autobiographical memories with popular music and strong emotional responses; these are often idiosyncratic experiences to certain listeners. In **Chapter 4** of this research project, qualitative data were collected regarding musical chills experiences, with numerous accounts describing autobiographical memories, such as the chills music playing at a parent's funeral, henceforth serving as a memory retrieval cue for this event. As autobiographical memories may serve to consolidate or reinforce social connections and relationships (Nelson, 1993; Harris, Rasmussen & Bernsten, 2014), these unique experiences with music may be potent elicitors of social chills, and may further be independent of the structural developments and qualities of the music. More broadly, some listeners may draw associations between pieces of music and other events or themes; one potential example of this in Western culture is the use of Pachelbel's *Canon in D* as music for weddings (Garrido & Davidson, 2019), a prototypical significant life event linked to being moved (Menninghaus et al., 2015). Notably, this piece was reported by numerous participants in **Chapter 4** of this project, but was avoided in subsequent experiments due to high levels of familiarity; however, whilst speculation, this piece may be a specific example of cultural associations attributed to music that might in turn elicit social chills experiences. However, the associations established by listeners between music and other themes or events are likely complex, numerous and multifaceted.

To summarise the second component of the first level in this framework, individual differences, such as personality traits, processing styles, mood state, familiarity and idiosyncratic factors are essential in determining the type of chills experienced during music listening, in combination with the music being listened to and the processes it affords. The framework makes some speculative predictions regarding the effects of individual differences: Firstly, it is anticipated that in the context of the big five personality traits, those who score high in agreeableness might experience more social chills (Panksepp, 1995), those high in extraversion may experience the higher arousal vigilance chills, and openness to experience has no apparent predictive capacity for distinct musical chills; secondly, it is expected that trait empathy, given its relationship with being moved (Eerola et al., 2016) and some types of chills with multimedia (**Chapter 7**), is associated with social chills experiences, with a similar relationship predicted for those with more of an empathising processing style, in contrast to systemisers who are expected to experience vigilance chills more readily. Finally, it is hypothesised that familiarity has an effect at the level of distinct chills, as opposed to overall chills frequency, with familiar music resulting more often in social chills, given the capacity for further extra-musical processes and aspects such as memories, identification with artists or sub-culture, and other associations; these 'personal meanings' have been suggested to be important factors in musical chills experiences across some listeners (Panksepp, 1995).

Listening Context

The third and final component of level one in the distinct musical chills framework is the listening context. Currently, it is difficult to surmise in detail the effects of different listening contexts, given the substantial variety of circumstances in which musical engagements occur. Research on musical chills reflects the broader music and emotion field, in that the situational factors of music listening are rarely investigated; however, some studies have attempted to address this complex facet of the experience. For example, Egermann et al. (2011) found no clear, overall differences in the frequency of chills experiences between listening alone or listening with friends; despite this, there was notable inter-individual variations across these two conditions, suggesting that for some listeners the social listening context was more effective with regards to experiencing chills, linking potentially to some individual differences highlighted in the previous section. Nusbaum et al. (2014) also utilised experience sampling methodology to explore musical chills in everyday circumstances, suggesting that whilst chills occurred in a variety of circumstances, one important factor was whether the music was chosen to be listened to or not, with more chills experienced when the listener had chosen the music themselves. In **Chapter 4** of this project, a more holistic picture of listening contexts in which musical chills had occurred was presented, resulting in a broad variety of circumstances linked to chills, such as listening alone or with others, listening to recorded music or watching live performances, and listening during mundane tasks such as driving, during transportation, or whilst working. These contexts undoubtedly affect levels of attention to the music, a factor considered crucial for chills by Grewe et al. (2007); however, there is no immediate grounds for a speculative proposal of systematic patterns across listening contexts and distinct musical chills responses; therefore, an unfortunate and limiting factor of the existing literature and current research trajectory is that the listening context is acknowledged in the current framework as an essential aspect that interacts with listener traits and the music being listened to, but no hypothesis is presented with regards to vigilance or social chills with music.

Summary

To summarise the first level of the current preliminary framework, the starting point for any musical chills experience must be derived from the three central components of a music listening experience and how they interact; these refer to the music being listened to, the individual qualities of the listener, and the context in which listening occurs. Notably, there are clear predictions for distinct musical chills when considering the music and its structural, psychoacoustic and narrative qualities. Furthermore, there are some predictions made in the framework regarding individual differences such as personality traits, processing style, mood state and familiarity; finally, whilst context is significantly important for any emotional experience with music (North & Hargraves, 2008) and beyond (Barrett, Mesquita & Gendron, 2011), there is substantial variability across listening situations, and a sparsity of research on the topic, and as a result the preliminary framework offers no clear predictions in this regard. Furthermore, there are numerous, complicated interactions between the music, listener and situation which need to be acknowledged in the current research context; consequently, it is essential to state that, as highlighted in broader emotion science work, emotional experiences are highly complex (Gross & Barrett, 2011; Izard, 2007), and that this framework adopts a mechanistic approach only as a basis for developing an understanding of the chills phenomenon.

9.3.2 Level Two: Underlying Psychological Mechanisms

Following the first level of the framework comprised of the music, listener and situation, and the complex interactions between these components, the second level addresses the possible psychological mechanisms underlying the subsequent vigilance or social chills experiences. These are crucial, hypothesised processes that bridge the distance between musical features, individual differences and contexts, with the resulting psychophysiological experiences. At this level, the model separates into two processes, reflecting both vigilance and social bonding theories; for each chills experience, the choice of which process path to follow is largely dependent on the first level of the framework, namely the complex combination of music, listener and situation. In addition, this second level can be contextualised in terms of the BRECVEMA framework of music and emotion (Juslin, 2013; Juslin et al, 2010; Juslin & Västfjäll, 2008); introduced in **Chapter 2**, this framework is comprised of eight proposed mechanisms of music and emotion more broadly, labelled brain stem reflexes, rhythmic entrainment, evaluative conditioning, contagion, visual imagery, episodic memory, musical expectancy and aesthetic judgment.

Vigilance Mechanisms

The first processes formalised in the framework are that of vigilance, fear, attention and arousal. These processes may be engaged through listening to music characterised by sudden structural changes in music, such as crescendos, unprepared harmony and sudden textural changes (Panksepp, 1995; Sloboda, 1991); furthermore, associated psychoacoustic parameters may include loudness and auditory roughness (Arnal et al., 2015; Nagel et al., 2008). Listeners high in extraversion, who prefer systematic processing styles, and are unfamiliar with the music may be more likely to engage vigilance mechanisms during the music listening experience. In relation to proposed fear and vigilance processes that might underlie chills, via the evolutionary threat-signalling functions of goosebumps (Darwin, 1872), there are several candidate mechanisms that might specifically be recruited. The first is the brain stem reflex, an ancient, low-level reaction to external events that demand immediate attention; in the musical context, a sudden dynamic or textural change may be sufficient to engage with this mechanism. The second mechanism is that of musical expectancy, which whilst related to brain stem reflexes, is treated here as a process sensitive to musical syntax, as opposed to lower-level psychoacoustic parameters such as loudness or auditory roughness; an example of this might be experiencing chills in response to new or unprepared harmonies in music (Sloboda, 1991). The third proposed mechanism underlying vigilance and fear processes is auditory looming (Ghazanfar et al., 2002; Neuhoff, 1998; 2001); this may more closely accommodate the relationship between chills and gradual increases of dynamics in music, such as the crescendo.

Overall, these three mechanisms may be mapped intuitively on to processes of fear, vigilance and attention, given that they can be understood in terms of an expression of potential threat; brain stem reflexes and musical expectancy might both be understood in terms of surprise, and the maladaptive failure to predict future events, resulting in immediate worst-case scenario appraisals (Huron, 2006; Huron & Margulis, 2010). Auditory looming, on the other hand, may be a qualitatively different process, in that prediction is recruited earlier, essentially before an 'encounter' as it were. At this preliminary stage of developing the framework, no differing effects are specified with regards to which mechanism might be engaged, and how they might co-occur or interact; however, these are essential questions not just for chills, but for music and emotion more broadly.

Social Bonding Mechanisms

The other main branch of the distinct musical chills framework has its foundations in social bonding and empathic processes. In contrast to the conditions in the first level of the framework that afford fear and vigilance processes, social and empathic processes may instead be engaged by music with moving, bittersweet and melancholic narratives, expressed instrumentally with the human voice, super-expressive instruments (Juslin, 2001), or with lyrics; additionally, listeners who are high in trait empathy, prefer an empathising cognitive style, are familiar with the music, and show a level of mood congruence with the expressive character of the music, may be more likely to activate social bonding processes during music listening as opposed to vigilance. These broader processes can also be framed with regards to underlying mechanisms of music and emotion. In these cases, numerous mechanisms are implicated, such as contagion and episodic memory. Contagion, as highlighted in **Chapter 2**, is characterised as an automatic, low-level process in which the emotions perceived in another person, object or stimulus, are similarly felt (Hatfield, Cacioppo & Rapson, 1993); whilst it is unclear how this might occur, the human mirror neuron system has been highlighted as a possible neural system for the mechanism (Iacoboni et al., 2005; Overy & Molnar-Szakacs, 2009; Rizzolatti & Craighero, 2004), such that the brain prepares or enacts actions perceived, potentially resulting in a proprioceptive feedback and spreading of the affective qualities normally associated with the action. Interestingly, Juslin (2013) notes that contagion may result in feelings of communion and oneness during music listening, factors central to experiencing chills alongside feelings of being moved or kama muta (Fiske et al., 2017; Schubert et al., 2018), and some chills experiences investigated in **Chapter 7**. A further mechanism is that of episodic memory. Although highly idiosyncratic, music can serve as a retrieval cue for certain memories, and depending on the quality of the memory, this may contribute to the elicitation of social chills with music; for example, Baumgartner (1992) reported that memories linked to music were linked to social events, such as activities with friends, or romantic relationships and interactions. Music-evoked memories have further been linked to states of nostalgia (Janata et al., 2007), a mixed affective response that shares similarities with being moved (Johnson-Laird & Oatley, 1989; Wildschut et al., 2006; Wildschut et al., 2010). The role of familiarity with music in chills responses is most apparent in relation to episodic memory, and the mechanism may be largely independent of specific qualities or characteristics of the music.

Besides contagion and episodic memory, a further construct is empathy, although this is a complex concept difficult likely denotes a series of psychological mechanisms (Cuff et al., 2016). Empathy, in the current context, is distinguished from contagion, as a higher-level process that maintains a self-other distinction and is a conscious process (Laurence, 2007), which involves understanding and reacting appropriately to the emotional states or circumstances of others. Whilst trait empathy is characterised by several facets (Davis, 1980), *empathic concern*, a culturally appropriate response to another in need of comfort or support, has been linked to the experience of goosebumps, and characterised as a special instance of kama muta (Zickfeld et al., 2017). In the current dissertation, empathic concern was suggested to underlie experiences of *cold chills* with some multimedia items in **Chapter 7**. In addition to empathic concern, *shared experiences* characterised by social bonding, togetherness and communion, may also be important processes or mechanisms linked to social chills with music, which are not encapsulated in existing approaches to music and emotion mechanisms. Shared experiences, described as consubstantial assimilation by Fiske (2004), refers to experiences of equivalency across bodily motion, motor production, appearance and aims; various multimedia items in **Chapter 7** expressed instances of shared experience, all of which were associated with *warm chills*. Importantly, although no clear predictions were made regarding subtle variations in chills experiences derived from differing fear and vigilance mechanisms, the framework anticipates that with social chills, the valence of the experience may be affected by the specific induction mechanism engaged by the stimulus in question; in other words, empathic concern would result in more negative social chills, and shared experience would lead to more positive social chills, reflecting to an extent the goosetingles and coldshivers distinction suggested by Maruskin et al. (2012).

9.3.3 Level Three: Response, Organisation and Evaluation

At the third and final level of the distinct musical chills framework, the main components to be considered are subjective feelings, bodily reactions and physiological responses, the speculative organisation of activation patterns depending on whether chills are elicited through vigilance or social bonding mechanisms, and the role of conscious aesthetic judgments. In other words, this level denotes the type of chills experienced. By this stage in the framework, the combination of music, listener and situation has determined which induction path is recruited, and the characteristics of the music and the listener have further specified which vigilance or social mechanisms are engaged (i.e. brain stem reflex or musical expectancy, empathic concern or shared experience). The third level therefore represents the main shift from induction to outcome, not unlike the two overarching pre- and post-event segments of Huron's ITPRA model of expectation (2006).

Vigilance Chills

Following the vigilance induction route, the proposed outcome is an experience labelled vigilance chills. These chills are accompanied by goosebumps that are theorised to be elicited through their evolutionary threat-signalling functionality. Vigilance chills might be characterised as an initial fight-or-flight response to an external trigger or event that requires attention; as a result, the framework anticipates a pattern of physiological responses associated with fight-or-flight, such as increases in skin conductance (Bradley et al., 2001; Bradley et al., 1993; Craig, 2005; Salimpoor et al., 2009), and decreases in skin temperature (Baumgartner et al., 2006; Collet et al., 1997; Ekman et al., 1983; Krumhansl, 1997; Salimpoor et al., 2009).

Regarding bodily reactions, vigilance chills may be accompanied by expressions or behaviours indicative of awe, such as widened eyes, a dropped jaw, and notable changes in breathing (Yaden et al., 2019). Additionally, the subjective feeling component of vigilance chills may also reflect high arousal experiences of awe linked to vastness and the need for accommodation (Keltner & Haidt, 2003); feelings of excitement, stimulation, and surprise may be some further examples, all of which were reported across some participants in **Chapter 4**.

The framework also makes a highly speculative prediction regarding the sequential organisation of these emotion components (Scherer & Coutinho, 2013). Regarding vigilance chills experiences, it is suggested that the physiological response is the initial outcome from fear and vigilance mechanisms; this is comparable to earlier emotion theories posited by James (1894) and Lange (1885), who stated that conscious emotional experience may be derived from interpreting bodily and physiological changes (see Schachter & Singer, 1962). In the current context, this plays out as an event in music that triggers an immediate, worst-case scenario appraisal and organisation of physiological systems, that is largely automatic and unconscious (Huron, 2006); it is important to note however that the prevailing context surrounding the event might still be processed at this stage (Barrett, 2006b; Russell, 2003), potentially modulating the capacity for music to elicit vigilance chills. Following the physiological activation and fight-or-flight preparation accompanying goosebumps, these changes are rapidly perceived and interpreted in the aesthetic context, distanced from 'real' pragmatic concerns (Menninghaus et al., 2017), allowing for a safe exploration of negatively valenced reactions. From here, Huron's (2006) proposed 'contrastive valence' process might occur, evolving from the initial negative, threat-based response, to a potentially more positive evaluation given the aesthetic circumstances. It is important to note however that this contrastive process has yet to be investigated and evidenced in music and emotion research.

Social Chills

In contrast to vigilance chills, when the music, listener and situation interact to engage with social bonding and empathic processes, including episodic memory, contagion or empathy, the resulting outcome is labelled social chills. These chills responses are accompanied by goosebumps that are theorised to be elicited through the other primary evolutionary function of thermoregulation, through a neurological coupling between thermoregulatory and socio-emotional brain systems (Panksepp, 1998; Panksepp & Bernatzky, 2002). In contrast to the fight-or-flight response implicated alongside vigilance chills, the physiological characteristics of social chills are less clear from the theoretical literature. Despite this, it was predicted that social bonding and empathic processes, less immediately pertinent for survival when compared to fear and vigilance, would result in lower levels of skin conductance; this was partially supported in **Chapter 8** of this dissertation, with lower tonic skin conductance accompanying social chills responses as opposed to vigilance chills. Furthermore, there is some evidence to suggest that skin temperature increases during experiences of social bonding, closeness or connection (IJzerman et al., 2012; Inagaki & Human, 2019; Inagaki et al., 2016), an opposite pattern of change to that predicted with vigilance chills; this temperature increase was also partially supported in **Chapter 8** of the current project, although differences between vigilance and social chills were small. As a result, this framework speculates that social chills are accompanied by skin temperature increases, and skin conductance increases that are not as pronounced as those accompanying vigilance chills.

Besides physiological responses, there are several bodily reactions predicted to occur alongside social chills. These reactions are encapsulated by recent conceptualisations of being moved and kama muta (Fiske et al., 2017; Menninghaus et al., 2015), and include tears (Wassiliwizky et al., 2017a), feeling a lump in the throat (Fiske et al., 2017), and a warmth in the chest (Algoe & Haidt, 2009; Seibt et al., 2017). Also, the subjective feelings that might be experienced during social chills responses include feeling moved, touched or stirred (Kuehnast et al., 2014), nostalgia, melancholy, bittersweet emotion, tenderness and affection. In **Chapter 7**, these experiences were found to cluster in a category labelled *moving chills*, which appears to be a variant of social chills predicted to an extent by trait empathy.

Finally, like vigilance chills, the distinct musical chills framework speculatively proposes a temporal sequence of outcomes for social chills. In contrast to vigilance chills however, there is no clear foundation for determining whether subjective feeling components follow or precede physiological or bodily changes; but intuitively, it may be possible that without engaging in some empathy or contagion process first, the goosebumps and accompanying physiological responses might not occur, especially given that the underlying procedure proposed is one of brain activity in socio-emotional systems resulting in a spreading activation to thermoregulatory circuits. Therefore, it is tentatively suggested that the subjective feelings derived from social bonding, connection and empathy, precede the physiological and bodily responses that comprise chills, although extensive research will be required to establish less speculative predictions with regards to temporality.

Aesthetic Judgment and Evaluation

The final aspect to consider in this third level of the framework is the notion of conscious aesthetic judgments (Juslin, 2013; Leder et al., 2004). This is a highly complex area of research, and for simplicity and project scope, a restricted set of aesthetic criteria proposed by Juslin (2013) will be the main reference point for this section; however, it is important to acknowledge the broader tradition of psychological approaches to aesthetic appraisals (Leder & Nadal, 2014; Pelowski et al., 2017), often encapsulating many aspects of aesthetic engagement such as perceptual processes, complexity, arousal (Berlyne, 1971), prototypicality (Martindale & Moore, 1988), classifying art objects, individual differences and engagement contexts.

The conscious judgments and appraisals of our musical engagements and chills experiences likely play a crucial role in the evaluation of the response as positively or negatively valenced, and in some cases these aesthetic judgments may precede and provide a foundation for certain chills experiences. Juslin (2013) describes several criteria from which aesthetic judgments of music might be made; these include *beauty, expression, novelty, emotion, skill, message, style,* and the *sublime*. These criteria are variously informed by sociocultural background (such as when referring to musical style), musical background (for example when considering skill, novelty and message criteria), and likely other factors. Additionally, these criteria are not considered equally important for all individuals, with a hierarchy of importance more probable, that likely differs across listeners (Juslin & Isaksson, 2014; Juslin, Sakka, Barradas & Liljeström, 2016).

In the context of the distinct musical chills framework, aesthetic judgment criteria may be differentially crucial across vigilance chills and social chills; furthermore, aesthetic judgments as a broad process may be recruited in varying ways. Regarding vigilance chills, given the automaticity and adaptive value of the numerous mechanisms implicated, such as brain stem reflexes, musical expectancy and auditory looming, the framework anticipates that aesthetic judgments offer a contextualisation and evaluation of the chills response after it has occurred. For example, depending on how music violates harmonic expectations, a listener may perceive or understand the goosebumps as a response to a beautiful, novel or sublime chord change, resulting in a pleasurable, positive experience which, if of sufficient intensity, may result in feelings of awe; however, this may not be the case for all aspects of expectation, and likely depends on the aesthetic criteria hierarchy, background of the listener, and listening context. In contrast, for social chills, with an emphasis placed on social bonding and empathic processing as preceding the chills response, aesthetic judgments may comprise, alongside social bonding mechanisms, the foundations for social chills. Implicated criteria here may include expression (for example of characters, identities or social aspects), emotion (that listeners may share), and message (communicating or perceiving ideas in music); music that is judged to meet these criteria may be better suited to engage and intensify CSRs, possibly resulting in social chills experiences.

A crucial caveat with discussions on aesthetic judgments, mirroring the suppositional and speculative nature of how the present framework addresses the organisation of emotion components in chills, is that the role of aesthetic judgments is highly complex, and the previous musings on their role and impact in vigilance or social chills is purely conjectural. For current purposes, the distinct musical chills framework proposes that aesthetic judgments play a role in all chills experiences with music; however, it is difficult to ascribe specific effects and impact of various aesthetic judgments and criteria, especially considering there is little agreement in the complex field of aesthetics and psychology as to how aesthetic judgments are formed and deployed, or even what they might be (Juslin, 2013; Leder et al., 2004; Leder & Nadal, 2014; Menninghaus et al., 2017; Pelowski et al., 2017). A thorough investigation and discussion of aesthetic appraisals is therefore far beyond the scope of this research project, but should be acknowledged.

9.4 Limitations of the Framework

In addition to the limitations inherent in the methodologies employed across the five studies in this project, there are three important shortcomings or immediate points of contention regarding the proposed distinct musical chills framework.

Firstly, it is important to keep in mind that, whilst the framework described in this final chapter is derived and based on existing theoretical formulations, and some degree of evidence, there are multiple aspects, mechanisms and interactions included within the framework that are, for the most part, hypothetical and speculative. This is reflected holistically by the lack of understanding generally regarding the musical chills phenomenon; for example, the interactions between music, listener and situation are not clear, nor are they adequately addressed in the current or previous research. In addition, the effects of different underlying mechanisms and processes within the vigilance or social induction routes of musical chills are relatively unknown, and in fact not all processes are comprehensively supported in the current research, such as musical expectancy as delineated by Juslin (2013). Therefore, it is essential to keep the overarching context transparent when presenting the distinct musical chills framework, namely that the current understanding and knowledge of the chills phenomenon is poor, and further research is required on the topic to be confident about what exactly is being studied.

The second limitation of the distinct musical chills framework concerns the foundations of the theoretical underpinnings and ideas of vigilance and social chills responses. Importantly, chills have often been defined as a subjective emotional experience accompanied by goosebumps, shivers down the spine or tingling sensations; this definition has also repeatedly been used across most studies carried out in the present dissertation. However, the theories that have been developed and extended in the current work, namely the vigilance and social bonding theories of chills, are both formulated based on the goosebumps response and its evolutionary functions. This is problematic, especially in relation to the common definitions employed for the chills phenomenon; given the diversity of biological underpinnings of goosebumps, shivers, and the elusive, poorly understood tingling sensations, developing theories based on one of these physical responses is potentially limited, reductionist and not sufficiently able to encapsulate chills experiences. Whilst this may be the case, the focus on goosebumps was motivated by the fact that it remains the only physical response to be objectively captured alongside chills reports from participants (Benedek & Kaernbach, 2011; Craig, 2005; Wassiliwizky et al., 2017a, 2017b); in contrast, shivers and similar muscular contractions have never been measured during musical chills, and tingling sensations, as currently reported in medical literature, appear to be immeasurable for the time being (Tihanyi et al., 2018). Therefore, there are reasons as to why the current distinct musical chills framework and hypothesis is theoretically derived from a focus on the goosebumps reactions; of course, it is important to keep in mind that chills may be accompanied by shivers and tingling, and that further research should aim to elucidate the physical reactions and to refine the definitional scope of the phenomenon.

The final, and perhaps most difficult limitation with the distinct musical chills framework is related to the degree of mutual exclusivity regarding the vigilance and social induction routes, and the hypothesised affective consequences of these processes. This is exemplified particularly by the methodology employed in the final study of this project, in which pieces of music were selected if they contained moments of sudden dynamic contrast; this was motivated by sudden contrasts possibly engaging vigilance processes via expectations or auditory looming, and social bonding processes by possibly reflecting key moments in imagined narratives (Margulis, 2017), allowing for a freedom to bias participants to experience vigilance or social chills with the same piece. Whilst this is a strength of the methodology, this also is the exact limitation of the current framework, namely that structural features of the music may be, in any one case, able to engage with both vigilance and social bonding processes; if so, this makes predictions and causal manipulations highly difficult to achieve, and leaves open the possibility that in some cases vigilance and social processes are engaged simultaneously. This lack of mutual exclusivity is also apparent when discussing the emotional characteristics of vigilance or social chills, namely awe and being moved. In the proposed framework, awe is one possible affective state that comprises vigilance chills experiences, in that awe is related to key appraisals such as the need for cognitive accommodation, and encounters with vastness (Keltner & Haidt, 2003; Shiota et al., 2007). In contrast, being moved, or kama muta, has been designated as a common emotional outcome alongside social chills responses, in that they may be elicited by intensified communal sharing relations, experiences of social bonding and equivalence, and empathic processing

(Benedek & Kaernbach, 2011; Fiske et al., 2017; Menninghaus et al., 2015; Wassiliwizky et al., 2015; Zickfeld et al., 2017). However, recent research on the experience of awe has related the emotion to prosocial cues and functions; awe has been associated with feelings of the small self (Spears et al., 2011), and increases in prosocial and altruistic attitudes (Piff et al., 2015; Preston & Shin, 2017; Stellar et al., 2018), suggesting that awe serves as a response that motivates the assimilation of oneself into a social system or hierarchy and feeling one with society. It is not clear whether some of these findings relate more to the positive valence and pleasure of awe, as opposed to the qualitative idiosyncrasies of the awe response, but the social connotations of awe run in parallel to those predicated in accounts of being moved; the similarity between these experiences was also discussed earlier by Konečni (2005). As discussed in **Chapter 3**, these experiences may be difficult to separate in some circumstances, although it appears likely that there are sufficient distinctions between the responses: Awe has often been characterised by a level of fear or vigilance, whereas being moved and related states have not; also, being moved and kama muta emphasise social equivalence, as opposed to awe that emphasises the assimilation into existing hierarchies that highlight social differences between oneself and another person or event; finally, there are numerous instances, particularly when considering the process of empathic concern, that may invite experiences of being moved, but theoretically fail to meet any prerequisite for awe, although these are poorly understood. Therefore, this difficulty in distinguishing between the theoretical induction routes of vigilance and social chills in relation to musical structure is a notable limitation, alongside the points of crossover and similarity between awe and being moved as respective affective indicators of different types of chills; to discern the extent of this difficulty and its accompanying issues however, more research will be required, and this will likely have helpful repercussions for studies in transformative and peak emotions, and perhaps religious and spiritual experiences.

9.5 Implications

The distinct musical chills framework serves as a preliminary outline for understanding the theoretical and psychological underpinnings of chills experiences with music, and potentially other aesthetic stimuli such as films, images and poetry. The three different levels of the framework are informed by the existing literature on musical chills and musical emotions more broadly, and are also derived from the novel research carried out as part of the current dissertation. To summarise, there is evidence for at least two distinct types of chills experiences with music, those derived from vigilance mechanisms stimulated by various psychoacoustic parameters and structural features in music, and those resulting from social bonding and empathy processes engaged by narrative qualities or elements of human expression in music, and extra-musical aspects such as episodic memory. These also reflect the two main evolutionary functions of goosebumps, namely threat-signalling and thermoregulation. Finally, the framework not only specifies differences in the induction route for vigilance and social chills, but also denotes several aspects of distinction in the experiential outcome; the two types of chills are hypothesised to be distinguishable based on physiological activity and subjective feeling. Notably however, the overall experience of either type of chills response during music listening is dependent on highly complex aesthetic judgments, cultural membership, identity, and other factors.

In the following, closing sections of this chapter and overall dissertation, the implications of the distinct musical chills framework will be discussed firstly with regards to interpreting the extant musical chills research, secondly in relation to underlying mechanisms of music and emotion more broadly, and finally in the context of broader emotion theory, and how studying a specific phenomenon like musical chills can inform the discourse in the ongoing emotion science literature.

9.5.1 Musical Chills Research

The main summaries and conclusions from the current research project have notable implications for interpreting existing musical chills research, and these concern: The issue of investigating different chills experiences without specification of the phenomenon or stimuli utilised; interpreting inconsistencies across neuroimaging and psychophysiological approaches; and the effects of individual differences on the quality of chills experienced, as opposed to the frequency of occurrence.

Specification of Musical Chills and Stimuli

Firstly, if we consider that, depending on the structural qualities and other characteristics in a piece of music, psychologically distinct chills experiences might be elicited, then there is the need for greater transparency regarding the stimuli utilised. Numerous studies have presented stimuli to participants to assess the elicitation of chills (Panksepp, 1995; Grewe et al., 2007; Guhn et al., 2007). However, whilst some consistencies are reported between chills and specific moments in some musical stimuli, the substantial variation of reports, and lack of chills responses in some participants, is often interpreted in relation to individual differences, levels of familiarity, and the idea that some listeners do not experience chills at all. Whilst there is some credence to these perspectives, an additional, important point for discussion concerns the possible differences in the chills experiences themselves. A notable example is the time-series analysis from Panksepp's work (1995), in which chills reports generally converged at a moment of sudden dynamic change in a Pink Floyd song, but were more evenly distributed in a piece by Air Supply. In the context of the distinct musical chills framework, it might be suggested that the sudden dynamic change elicited more consistent, structurally driven vigilance chills, whereas the larger spread of chills reports may be indicative of social chills that are derived from social cognition and extra-musical aspects that result in greater variability of response. In other words, whilst both types of chills are derived from aspects of the music, vigilance mechanisms are hypothesised to be based strongly on structural development in the music, and social processes are predicted to be more variable inter-individually, depending on perceiving a narrative and personal connection or relation to the piece. This is a crucial consideration for the existing literature, especially when considering that most research assesses chills reports in relation to structural and psychoacoustic analyses of the music; this approach is largely insensitive to the aspects of music listening that may be conducive to social chills experiences, and as shown in **Chapter 4** of the current dissertation, there is substantial value and insight to be gained by simply asking participants to describe these chills moments during music. Descriptions referring to social communion, union and feeling connected to music would not be accessible by traditional correlation approaches taken in musical chills research.

Bodily Reactions, Physiological Response and Brain Activity

Secondly, in the context of the distinct musical chills hypothesis, there are further avenues for understanding previous findings pertaining to bodily reactions, psychophysiological responses and brain activity during chills; these inconsistencies have been documented at greater length in **Chapter 3**.

Regarding bodily reactions, it has been noted across the extant literature that chills may be associated with, and might co-occur with, other bodily responses; these include feeling a lump in the throat (Fiske et al., 2017), tears (Wassiliwizky et al., 2017a), warmth in the chest (Algoe and Haidt, 2009), and the autonomous sensory meridian response (Barrett & Davis, 2015; del Campo et al., 2016; Kovacevich & Huron, 2019; Poerio et al., 2018). Additionally, the sensation of chills, whether observed as goosebumps or reported as subjective tingling sensations that are difficult to quantify (Tihanyi et al., 2018), can be reported in numerous locations of the body (Craig, 2005; Goldstein, 1980; Panksepp, 1995; Sloboda, 1991). These variations might not be trivial, with phenomenological bodily sensations and their locations possibly corresponding to different emotional processes (Nummenmaa et al., 2018). A specific example in which the distinct musical chills framework is applicable concerns separable interpretations presented by Mori and Iwanaga (2017) and Wassiliwizky et al. (2017a) regarding the relationship between chills and tears. Mori and Iwanaga (2017) reported psychophysiological distinctions between experiences of chills and tears with music, mainly in the form of increased skin conductance during chills as opposed to tears; in contrast, Wassiliwizky et al. (2017a) utilised participant-selected, emotionally moving film scenes to elicit goosebumps and tears, noting that the two responses occasionally co-occur, resulting in intense emotional experiences.

These differing conclusions can be reconciled in the context of distinct chills responses, in that vigilance chills are separable from tears and crying, but social chills may share more similarities with tears. This is especially evident when considering that Mori and Iwanaga (2017) utilised musical stimuli to distinguish between chills and tears, whereas Wassiliwizky et al. (2017a) used film scenes to demonstrate co-occurrence. It is likely that music, with its emphasis on structural development through time and subverting of expectations, has a more innate capacity than film (though consider horror genres) to elicit vigilance chills separable from tears; concordantly, film scenes expressing explicit social narratives may more readily elicit social chills associated with tears, in comparison to music that does not always explicitly communicate social cues or narratives. These diverging results may be a prime example of not specifying or operationalising stringently enough the chills phenomenon being investigated, resulting in an inconsistent development of research; in a most extreme scenario, every study may potentially be targeting different chills experiences.

Next, there is the degree of variability regarding physiological activity underlying chills. Skin conductance is consistently associated with chills, but there are occasional null or variable results (Blood & Zatorre, 2001; Grewe et al., 2010; Mori & Iwanaga, 2014; Rickard, 2004). Heart rate patterns are somewhat inconsistent during chills (Blood & Zatorre, 2001; Grewe et al., 2009; Guhn et al., 2007; Sumpf et al., 2015), as are findings for respiration rate (Blood & Zatorre, 2001; Grewe et al., 2010; Mori & Iwanaga, 2017; Salimpoor et al., 2009, 2011; Sumpf et al., 2015) and skin temperature (Blood & Zatorre, 2001; Salimpoor et al., 2009). These differences may be understood to an extent by considering methodological distinctions across the studies, such as the resolution at which physiology is measured (e.g. alongside button presses, averaged across a stimulus, or during piloerection observations); however, the differences might also be interpreted effectively in the context of the distinct musical chills framework, again suggesting that the physiological variations are potentially meaningful, and require further investigation and direct comparison in relation to hypothetical distinctions across chills experiences.

Finally, a similar argument can be made regarding the neuroimaging literature on chills responses, with a focus on inconsistencies in results across studies by Salimpoor et al. (2011), and Wassiliwizky et al. (2017b). Salimpoor et al. (2011) reported dopamine release patterns during experiences of musical chills, noting a distinction in activity between an epoch of time directly preceding chills reports, and the chills themselves; the 'pre-chill' was characterised by dopamine release in the caudate, a component of reward circuitry and the dorsal striatum, whereas the onset of chills was accompanied by decreases in caudate activity, and increases in the nucleus accumbens (NAcc), often described as a hedonic hotspot in the brain (Castro & Berridge, 2014). In contrast, Wassiliwizky et al. (2017b) employed a similar temporal analysis of brain activity alongside chills elicited by poetry, and reported opposing results: The 'pre-chill' was accompanied by higher levels of NAcc activity compared to the chills onset, and there was increased activity in the anterior insula during the 'pre-chill'. It is difficult to explain some of the inconsistencies given the complexity of interpreting neuroimaging results; some possibilities may include individual differences in brain structure and activity patterns, the methods used (e.g. PET or fMRI scans), and most pertinently, the stimuli and experiences being examined. It might be possible, and likely, that depending on whether participants experienced chills with music (Salimpoor et al., 2011) or poetry (Wassiliwizky et al., 2017b), the neuroimaging or blood-oxygen-level-dependent results may vary;

however, it is difficult to describe in this case what differences might be expected, and this further inconsistency in the chills literature serves to re-iterate the need to better operationalise the experiences being examined.

Individual Differences

Finally, there is the question of individual differences and their relationship with both the tendency to experience either vigilance or social chills responses. As highlighted, the extant literature is generally insensitive to possible psychological distinctions across chills experiences, and as a result correlations between chills and certain musical features might be overrepresented, and others missed. However, the subset of investigations assessing individual differences in relation to musical chills can also be interpreted differently in the context of the distinct musical chills framework, as highlighted in **Chapter 7**. Musical chills have been linked to various individual differences, but as stated earlier in this chapter, there are inconsistent findings with regards to most aspects studied. These inconsistencies may be explained to an extent by the distinct musical chills framework, such that whilst for some listeners, in combination with some pieces of music, correlations between personality traits (for example openness to experience) and chills experiences may or may not be apparent, but that is not to say that these relationships are or are not apparent in other listeners, and with other types of music. Importantly, echoing the discussions in **Chapter 7**, this research overall highlights a crucial next step for future work, understood as a shifting of perspectives from individual listener traits predicting the incidence of musical chills overall, to instead assessing how these trait characteristics might bias or push listeners to experience different types of chills. Furthermore, in understanding chills there will be a need to delineate the qualities and characteristics of non-responders, and explore more extensively the prevalence of chills with music; Huron and Margulis (2010) had estimated that roughly 50% of the population might not experience musical chills, but presently no study has comprehensively investigated prevalence, particularly in representative samples.

9.5.2 Mechanisms of Music and Emotion

Beyond the direct implications for understanding the previous research on musical chills, one of the broader aims of this research project was to utilise chills as an emotional phenomenon that might inform more holistic perspectives or ideas regarding emotions elicited by music. The BRECVEMA framework was introduced in **Chapter 2** as a specific example in which the current project might inform broader discourse, and what follows is a re-evaluation of the proposed mechanisms of music and emotion, in the context of results and data collected across the current dissertation.

The BRECVEMA Framework

The eight mechanisms of the BRECVEMA framework (Juslin, 2013; Juslin et al, 2010; Juslin & Västfjäll, 2008) offer numerous, testable hypotheses for music and emotion studies, but also several theoretical contexts in which to understand the current data collected. Interestingly, as denoted in the distinct musical chills framework, several mechanisms are implicated in vigilance chills and social chills responses to music.

Regarding vigilance chills, two key anticipatory mechanisms appear central, namely brain stem reflexes and musical expectancy. The brain stem reflex appears to be aligned with correlations between musical chills and sudden dynamic or textural changes (Sloboda, 1991). From a theoretical perspective, it is also intuitive to consider brain stem reflexes as a vigilance and attention mechanism, like startle reflexes (Bradley et al., 1993) or orienting reflexes (Sokolov, 1963), that might tap into the threat-signalling functionality of goosebumps. It appears that this mechanism might be important in high arousal responses to music, although it is unclear as to how brain stem reflexes directly affect the subjective emotional experience, particularly that of peak pleasure found during some chills (Blood & Zatorre, 2001; Salimpoor et al., 2011). A similar mechanism implicated in vigilance chills experiences is musical expectancy, considered a key component of musical emotions (Huron, 2006; Meyer, 1956; Steinbeis et al., 2006). According to Juslin (2013), whilst this mechanism may denote a response to an unexpected event, alike to brain stem reflexes, the mechanism is grounded in the processing of musical syntax, rules, and the statistical learning of regularities in music (Pearce et al. 2010). Interestingly, this mechanism has been an attractive and intuitive account of musical emotions and chills (Huron, 2006; Sloboda, 1991), but existing research associates expectancy mainly to experiences of arousal (Steinbeis et al., 2006); furthermore, in interpreting the data collected during the current experiments, it is not clear that musical expectations were extensively implicated in experiences of musical chills. In fact, when considering recent work on strong emotions with electronic dance music and its signposted structure (Solberg & Dibben, 2019), and an effective chills pieces such as Glósóli that builds linearly and predictably in dynamics and textural density up to a climax, there appears to be important opportunities in psychological research regarding the emotional consequences of the fulfilment of musical expectations. Of course, the generation of expectations during music listening are complex (Narmour, 1990; Schellenberg, 1996), and likely occur in relation to numerous structural levels at any one time, such as melody, harmony and rhythm; moreover, the expectation-based process is intuitively encapsulated in vigilance and attention theories of chills (Huron, 2006). However, considering the current chills project and existing research, it is unclear how musical expectancy directly underlies various emotional experiences with music, particularly strong responses such as chills.

Regarding social chills experiences with music, other mechanisms from the BRECVEMA framework have been implicated. Contagion, proposed by Juslin (2013) as the process of mimicking the perceived emotional expression in music, and thus experiencing the same state, may be important in social chills experiences, but not in direct relation to this unconscious process. Instead it is proposed in the distinct musical chills framework that contagion may serve as a foundation for shared affective experience between listener and music, and this equivalence may in some cases be sufficient for engaging social bonding processes through intensified CSRs; this situation may be comparable to the possible effects of mood congruence between listener and music, such that sad listeners prefer sad music (Lee et al., 2013), and the role of sadness in consolation and solace (Hanser et al., 2016; Saarikallio & Erkkila, 2007; Taruffi & Koelsch, 2014). However, emotional contagion during music listening appears complex, and it is not clear what the underlying processes might be; researchers have highlighted the possible role of mirror neurons and perception-action loops (Overy & Molnar-Szakacs, 2009), such that numerous musical instruments are expressive due to listeners processing them as human vocal productions and actions (Juslin, 2013); this has received some support in work by Koelsch et al. (2006). In the current research, contagion may most clearly be indicated in the piece Ancestral, which elicited chills by way of a virtuosic and expressive guitar solo, possibly suggesting a level of social bonding between listener and music (or perceived personas) that may be derived from lower-level contagion processes. The second mechanism linked to social chills with music is episodic memory. Across the BRECVEMA framework it is perhaps episodic memory that is most independent of the music and its structural qualities; instead, the extra-musical factors contributed by listeners to the overall experience appear to be crucial. There was support for the importance of memory for musical chills in **Chapter 4**, and in some cases **Chapter 5** involving Gustav Holst's Jupiter, and the elicitation of memory has clear connotations for social processes, bonding and re-affirmation of existing relationships (Nelson, 1993; Harris et al., 2014).

To summarise, the distinct musical chills framework, alongside previous literature and current data presented in this dissertation, implicates four mechanisms derived from the BRECVEMA framework (Juslin, 2013), and these are brain stem reflexes, contagion, episodic memory, and musical expectancy. The role of these mechanisms, with perhaps an exception of musical expectancy, has been re-affirmed by assessing strong emotional experiences with music in the current project; notably, these processes were originally linked to selected emotional outcomes (Juslin, 2013), resembling a basic emotion theory approach (Izard, 2007); however, given the diversity of experiences and emotional qualities accompanying chills, the current project further elucidates the complexities of these proposed mechanisms, the possible interactions between them, and the need to progress beyond simplistic 'mechanism-emotion' prediction patterns.

Missing Mechanisms

Whilst the current musical chills project supported various aspects of an existing musical emotions framework, there are numerous limitations, gaps or issues that the present research has identified. Specifically, there is the issue of auditory looming as a perceptual process that explains a subset of correlations between musical structure and emotion that other mechanisms may not, and the importance and pervasiveness of empathy in contrast to emotional contagion.

One of the structural characteristics of music consistently linked to chills is the crescendo (Panksepp, 1995). In **Chapter 4** of this project, participants described chills moments in music with labels such as build-ups, crescendos, swelling, and other synonyms that appear to describe a gradual increase in dynamic contour during a piece. Across the three listening experiments in this dissertation, Glósóli was used as an effective and consistent elicitor of chills; notably, the 'chills section' in this piece corresponds to the climactic conclusion of a long, gradual crescendo and build of intensity. Crucially, this musical characteristic, prevalent across numerous musical styles, is not immediately explained in the context of the BRECVEMA framework; brain stem reflexes encapsulate sudden, abrupt changes in dynamic or textural quality linked to chills, whereas musical expectations as purported by Juslin (2013) are not fully applicable to lower-level features in music such as psychoacoustic parameters, or in this case dynamics and loudness. Therefore, these mechanisms fail to encapsulate one of the more consistent correlations and causally tested relationships between music and chills responses. What is suggested, resulting from the current project, is the inclusion and specification of auditory looming as an important mechanism in the induction of emotion through music. Auditory looming is perceptually salient (Bach et al., 2009, 2008; Ghazanfar et al., 2001; Grassi & Darwin, 2006; Neuhoff, 1998, 2001; Neuhoff et al., 2009; Tajadura-Jiménez et al., 2010), and is not specific to music, mirroring the other mechanisms included in the BRECVEMA framework (Juslin, 2013); the process also holds significant explanatory power regarding the emotional impact of crescendos in music, although it must be noted, as suggested in **Chapter 5** of this project, that the localised emotional potency of certain musical structures is likely embedded in a complex context of interactions with all other preceding musical events and progressions in the piece (Lehne & Koelsch, 2015).

The other main limitation concerns the effects and role of empathy in musical emotions. Empathy is a complex construct (Cuff et al., 2016), and so these processes, in the current context, span a variety of experiences that might occur during music listening. Notably, empathy is rarely considered in the BRECVEMA framework; the newly added aesthetic judgment mechanism (Juslin, 2013) at times sits adjacent to empathy, when considering judgment criteria such as what is expressed in music or whether the music carries or communicates a message, but fails to explicitly refer to empathy as a distinct process. This was already an absence difficult to reconcile with the prevailing literature on music and empathy, especially considering musical group interaction paradigms (D'Ausilio, Novembre, Fadiga & Keller, 2015) and investigations into pleasurable sad music (Eerola et al., 2016); however, following the current research project there is a concern that the BRECVEMA framework omits a key mechanism of musical emotions in empathy. In turn, the existing mechanisms suggested by Juslin and colleagues do not fully reflect contemporary listening habits; Juslin (2013) highlights that most modern music is focussed around the singing voice, but the prevalence of lyrics in popular music, and simultaneous lack of research into lyrics and emotion, is an unfortunate present circumstance. The current research highlighted a privileged role of lyrics in musical chills experiences, and it is likely that these aspects of music provide an explicit narrative and persona to the music or performers, in turn affording the experience of empathy with music, feeling understood by music, and identifying one's own situations or experiences in music. Alongside auditory looming, the role of empathy in musical emotions is a crucial area for future research.

Rhythmic Entrainment and Visual Imagery Considerations

Although there are perhaps four mechanisms in the BRECVEMA framework that appear to be applicable to musical chills experiences, and as such have been re-affirmed or supported as processes underlying musical emotions more broadly in this project, there are some further, speculative considerations regarding mechanisms of rhythmic entrainment and visual imagery, and their potential role in the chills phenomenon.

Rhythmic entrainment is an interesting process in the current research context, especially given its applicability across numerous studies of musical group interactions (D'Ausilio et al., 2015), and in turn social relationships and empathy. For example, it has been suggested that experiences of joint drumming, singing and dancing between infants results in increased prosocial behaviours (Kirschner & Tomasello, 2009; 2010). Hove and Risen (2009) further showed that two partners tapping in synchrony showed increased feelings of social affiliation. More recently, a longitudinal study by Rabinowitch et al. (2013) highlighted that rhythm workshops resulted in increased levels of empathy in infants when compared to a control group.

Finally, Cirelli et al. (2014) found that by bouncing infants in synchrony with an experimenter, the infants would act more altruistically in a subsequent scenario with the experimenter. These results reflect more generalised literature linking synchrony, and potentially entrainment, to positive interpersonal engagements (Chartrand & Bargh, 1999; Kühn et al., 2010). In the BRECVEMA framework, rhythmic entrainment is often discussed at the level of psychophysiological signals, such as heart rate, entraining to an external musical rhythm or pulse (Juslin et al, 2010), with the changes in physiological arousal potentially resulting in changes in emotional state; however, entrainment might induce emotional responses at the neural, motor and social levels (Trost et al., 2017). The social level of rhythmic entrainment is pertinent to musical chills, especially considering the social bonding and empathic processes implicated in some chills responses. Entrainment and synchrony may serve as a foundation for contagion and empathic processes through motor mimicry (Scherer & Coutinho, 2013); Philips-Silver & Keller (2012) additionally highlight that a key component of entrainment to music serves to enable the sharing of affective states. This is in line with the Shared Affective Motion Experience model (Overy, 2012; Overy & Molnar-Szakacs, 2009), in which hearing music as a collection of intentional motor acts, and being able to synchronise with these, affords empathy and social bonding experiences at numerous levels of the music listening or performing process. In shared experiences or consubstantial assimilation (Fiske, 2004), a possible route to intensified CSRs and kama muta (Fiske et al., 2017), the equivalence of movement between people or entities is one of several key aspects. Notably, substantial emphasis is placed on group interactions in which music acts as a facilitator; for example, the social entrainment to music and synchrony of action across listeners may explain some peak experiences at concerts and raves (Bharucha

& Curtis, 2008; Takahashi & Olaveson, 2003). However, there is the intriguing possibility of similar processes when listening to music alone; an example of this might be heavy rock or metal music styles, that often have a 'heavy' breakdown phase, in which exaggerated head or body movements are encouraged, or perhaps triggered in some listeners. How this motor engagement and entrainment with music might affect the listening experience is not fully clear, but outcomes may include increased levels of pleasure and enjoyment (Janata et al., 2012; Zentner & Eerola, 2010); regardless, it is plausible, in the prevailing theoretical context, that overtly moving to a piece of music whilst listening alone may tap into social bonding or interaction mechanisms, with music potentially behaving as the social 'other' (Schäfer & Eerola, 2018). As a result, whilst the current studies have not encroached on the mechanism (although rhythmic entrainment was a highly-rated mechanism in recalled or experienced musical chills in **Chapter 4** and **Chapter 5**), there is an intuitive opening here to suggest that rhythmic entrainment during music listening experiences might be a further route to eliciting social chills, worthy of investigation.

Visual imagery is another mechanism from the BRECVEMA framework that is worth considering in the context of musical chills. This mechanism has rarely been assessed in relation to emotional experiences with music (Taruffi & Küssner, 2019); this is surprising given that visual mental imagery with music appears to be common (Küssner & Eerola, 2019; Taruffi et al., 2017; Vuoskoski & Eerola, 2015), and that Juslin (2013) predicts that the mechanism can lead to almost any emotional response. Crucially however, visual imagery is substantially complex, and there are present limitations in understanding the structure, function, intentionality and underlying processes of the mechanism (Taruffi & Küssner, 2019), alongside the possible conflation of visual imagery with other processes such as memory. Given these points, it appears that visual imagery may play a role in experiences of musical chills, particularly those underpinned by social bonding and empathic processes. Listeners might empathise with an imagined persona or narrative within the music (Levinson, 1997; Robinson & Hatten, 2012), and this may be partially derived from visual mental imagery processes; for example, Taruffi et al. (2018) reported an association between trait empathy and higher levels of visual imagery during sad music listening. The ability to conjure visual mental images whilst listening to music may therefore afford empathic experiences alike to those described by participants in **Chapter 4** of this project, ranging from perceiving social interactions and communion in pieces of music, to being able to relate to, and feel understood by, the music. These aspects exemplify possible occurrences of intensified CSRs linked to social chills (Fiske et al., 2017), and as a result there appears to be an important role that visual imagery mechanisms might play in some musical chills experiences.

9.5.3 Emotion Theory

The final level of implications of the proposed distinct musical chills framework concerns the broadest context of the current project, namely the psychological literature of emotion science and theory. As established in **Chapter 1**, perspectives on emotion can be holistically categorised into several branches (Gross & Barrett, 2011); these are *basic emotions*, *appraisals*, *constructionist* approaches.

Basic Emotions

Regarding basic emotion theory, in which emotions are innate, universal and irreducible, fundamental adaptive responses (Ekman, 1992; Ekman & Cordaro, 2011;

Panksepp, 1998), with distinct behavioural and expressive components (Darwin, 1872), there is some level of intuitive support found in the case of vigilance chills experiences. For example, if fear is considered as a prototypical example of basic emotion (Gray, 1987; Kreibig, 2010), then vigilance theory may implicate basic emotion theory in the experience of some musical chills; theoretically, brain stem reflexes, musical expectancy and auditory looming mechanisms (Ghazanfar et al., 2002; Juslin & Västfjäll, 2008) all carry adaptive value that could elicit predictable stimulus-response patterns and emotional outcomes. However, the current and previous research on musical chills suggests that the response is quite unpredictable. Moreover, from a strict basic emotion perspective, the vigilance theory should result in negatively valenced emotional reactions to urgent events; this is not the case, with a range of pleasurable emotional concepts ascribed to chills experiences that may be underpinned by vigilance mechanisms. Besides vigilance chills, there is little evidence in the speculative account of social chills responses that indicate basic emotion processes; these experiences are also difficult to predict, can be accompanied by a variety of emotional and affective qualities, and show no intuitive stimulus-response pattern. However, it is worth noting that in **Chapter 7** a possible distinction was made across social chills experiences, depending on whether shared experience or empathic concern processes were involved, although these directionalities may be encompassed by appraisal perspectives of emotion as well. A final consideration for basic emotion theory is that at a holistic level, vigilance theory and social bonding theory predict separable categories of emotion in awe and being moved; whilst this may be aligned somewhat with basic emotions, it is important to note that these concepts are highly complex and enigmatic, are not comprehensively distinguishable, and may have several variants or antecedents.

Appraisals

In the case of appraisal perspectives of emotion which emphasise the assessment and judgment of events and stimuli in the induction of emotions (Roseman & Smith, 2001; Scherer & Coutinho, 2013) and determining the intensity and character of emotional experience (Frijda, 2007; Scherer et al., 2001), the distinct musical chills framework offers some level of support. Vigilance chills responses, and their corresponding induction route in music listening contexts, reflect the fast and slow appraisal processes described by several scholars (Clore & Ortony, 2008; Moors et al., 2013). For example, in Huron's (2006) ITPRA model, where the original formulation for the current vigilance theory was proposed, expectancy violations in music (and this may be expanded to include brain stem reflexes and auditory looming) elicit a rapid, automatic worst-case scenario appraisal, subsequently followed by a slower aesthetic appraisal that considers the safe aesthetic context. Appraisal theory is supported by the possibility that maladaptive experiences (i.e. violated expectations) can result in highly pleasurable vigilance chills responses (Salimpoor et al., 2011); without cognitive appraisals, exploring these negative reactions in aesthetic contexts may be less intuitive. Similarly, there are instances of social chills that might be neatly encapsulated by appraisal perspectives, with an immediate example being the process of empathic concern. Empathic concern, a culturally congruent response to another person in distress or need of support (Batson, 1980; Davis, 1980), may solidify social relationships in realistic situations; however, in the detached form of aesthetic engagement, empathic concern with characters or identities in multimedia (**Chapter 7**) may be explored safely by participants, and be experienced as a fulfilling pleasurable process, given that no immediate actions can be taken. This has yet to be fully explored, but suggests that appraisal theory is further supported in several ways by the current project, reflecting music and emotion literature utilising this perspective (Scherer & Zentner, 2001; Zentner et al., 2008).

However, a necessary caveat remains the difficulty for appraisals approaches, often emphasising the aspects of goal congruence (Moors et al., 2013), to explain strong positive emotions (Tong & Jia, 2017). Currently, it is unclear how appraisal processes result in experiences of awe, being moved and other complex emotions; Frijda and Sundararajan (2007) attempt to subvert this issue by designating 'coarse' and 'refined' emotion distinctions, and Zentner et al. (2008) act similarly in their distinction between utilitarian and aesthetic emotions. However, understanding whether emotional induction processes and experiences with music require a specialised explanation (e.g. a distinct appraisal process) is a topic for further work.

Constructionist Approaches

Finally, concerning constructionist approaches to emotion, it is difficult to highlight any direct evidence for psychological or social constructionism; instead, there is holistic, adjacent evidence for these approaches when considering the substantial and multifaceted levels of variation found across the current research project, and in the extant literature on chills, mirroring the statement that 'variation is the norm' with regards to emotion (Barrett, 2017). As stated in **Chapter 3** and the current chapter, variation exists across almost all aspects of the chills phenomenon including elicitors (and their features), subjective feelings, bodily and physiological reactions, and individual differences. Any reductionist and restricted approach to emotion theory struggles to encapsulate this degree of variability (see also Barrett, 2006a), although when the findings are broken down to an interpretation of vigilance and social chills, various perspectives can be applied in some cases. For example, the vigilance theory of musical chills resembles the James-Lange theory of emotion (James, 1884; Lange, 1885), and more recent conceptualisations of core affect (Barrett, 2006b; Russell, 2003), in that goosebumps are first elicited through vigilance mechanisms engaged by the music, and are subsequently perceived and appraised in conjunction with existing knowledge of emotion concepts, language and the aesthetic context. Despite this, the overall sentiment and conclusion from the current research, and a foundational reason for the novel distinct musical chills framework, is that the experience of chills can be substantially different across individuals and music listening engagements; some induction routes and experiences may resemble stimulus-response patterns indicative of basic emotion theory, whereas others reflect appraisal and constructionist approaches. As it stands, there is evidence (or rather, the absence of evidence for other emotion theories) for an applicable psychological and social constructionist approach to musical chills (see also Cespedes-Guevara & Eerola, 2018), although it may take some time to robustly embed the phenomenon as a case study within the broader emotion science literature.

Summary

To summarise the implications of the distinct musical chills framework for emotion science research, it appears that, when considering the chills phenomenon holistically, that the central interpretation is that chills reflect appraisal and constructionist approaches, but do not support basic emotion tenets, especially given the pervasive variability of the response across aesthetic engagements. It is essential to note that these conclusions are broad, although acknowledging central emotion theories in music and emotion work is important for developing a coherent research field. One final consideration regarding emotion science implications is that the current project worked with a liberal working definition of emotion, focussing on various emotion components and their concurrence in time (Scherer, 2009); however, a pivotal, outstanding question concerns the classification of chills as an emotion. For example, is the emotional response largely characterised by the physical and bodily responses, or from the perspective of Barrett (2013), are chills only emotional experiences when conceptualised and ascribed linguistic labels by the person? This latter perspective further raises issues of what chills responses reflect in terms of core affect (Russell, 2003), and to what extent the response is incorporated in peoples' construction of emotional experience and reality. These are larger scale, theoretical, and perhaps philosophical, issues with the phenomenon of chills that may need to be considered and acknowledged in future research.

9.6 A Novel Research Agenda

Whilst the phenomenon of musical chills has received notable attention in music and emotion research, and the current research project has aimed to address several key limitations in the extant literature, the understanding of chills elicited by music remains in its infancy; furthermore, whilst the present dissertation addressed several outstanding questions concerning the emotional characteristics of chills, whether the response can be causally manipulated, and whether chills are a coherent psychological construct, the five studies documented here raise multiple further questions that are essential to developing musical chills research. Therefore, the final main contributory section of this dissertation aims to propose several avenues for future work that comprise a novel research agenda for musical chills; these routes include advancing causal manipulation paradigms for musical chills experiments, testing aspects of the preliminary distinct musical chills framework, investigating individual differences in the context of significant variations in musical chills experiences, and developing a chills music corpus for large-scale feature extraction and music information retrieval studies.

9.6.1 Causal Manipulation Developments

The first avenue for further work concerns the development and refinement of causal manipulation approaches to musical chills. This is essential work for the advancement of chills research, particularly given the existing correlational approaches and results (Grewe et al., 2007; Grewe et al., 2009; Guhn et al., 2007; Nagel et al., 2008; Panksepp, 1995; Sloboda, 1991), and especially for being able to explain why and how music can elicit the response. Until now, almost no causal work had been carried out on musical chills; this is somewhat understandable, given the lack of clear stimulus-response patterns, a degree of unpredictability in the experience, and difficulties with eliciting strong emotions in experimental settings. However, the current research project suggests this can be achieved with the correct preparations, stimuli and participants. Both **Chapter 5** and **Chapter 6** of this project serve as a proof-of-concept foundation for further iterations of the causal approach to musical chills; importantly, these are only the initial methods and paradigms tested, and there is substantial potential in developing these approaches further. For example, psychoacoustic manipulations, whilst complex, appear to be a plausible method for causally assessing musical chills, and musical emotions more broadly. The next steps concern constructing a more robust methodological approach, in which psychoacoustic parameters can be manipulated in isolation, reducing the effects that cascade to other related features; a notable example of this may be altering loudness levels, whilst maintaining the qualities of spectral roughness and flux, although these features might together represent a more ecologically valid perceptual composite. A further key consideration with the causal manipulation approach is to develop approaches that assess the impact and effects of preceding, local structural contexts in a piece that might facilitate the chills potency of certain sections within the music; for example, the dynamic and textural climax of Glósóli may be augmented or diminished in its capacity to elicit chills, depending on the preceding musical developments and patterns provided to listeners. This is crucial work that might also inform broader theories and models of musical tension (Lehne & Koelsch, 2015).

9.6.2 Testing the Distinct Musical Chills Framework

The second main line of future research concerns the novel distinct musical chills framework, proposed as a culmination of the theoretical review and studies in the current dissertation. There is an essential question for work on musical chills concerning the two main theories and underlying induction routes of the response, namely vigilance or social bonding mechanisms. Alongside existing considerations that chills may not reflect a unified psychological construct (Levinson, 2006; Maruskin et al., 2012; Panksepp, 1995; Pelowski et al., 2017), some key next steps for musical chills investigations concern being explicit and cognizant of the phenomenon that is being studied; for example, future psychophysiological and neuroimaging work should attempt to contextualise results and findings in the context of the underlying processes of musical chills proposed in the current project, as it might be misleading or insufficient to refer to chills as indicators of broader hedonic experience. Additionally, there is substantial potential for future research in terms of causally addressing and testing predictions and hypotheses contained within the distinct musical chills framework presented in this project; consider for example the experimental manipulation of lyrics in music to affect or negate the explicit narrative that readily affords social chills, or comparisons of music arranged and performed in different ways to assess corresponding effects on musical chills. Also, further development and replication of the paradigm used in the final study of this project (**Chapter 8**) would be an important advancement for research on chills and musical emotions more broadly, to understand further whether awe and being moved are accurate emotional markers of vigilance and social chills, and to better identify the magnitude of differences across physiological activity patterns. This experimental paradigm serves as a robust method in that the same piece of music, with the appropriate structural features, might be accompanied by different visuals or prior information to bias listeners towards vigilance or social chills, and should be extended and refined.

9.6.3 Individual Differences and Musical Preferences

As highlighted when discussing implications of the distinct musical chills framework for existing work, a central progression for musical chills research is to consider shifting the perspective and approaches taken in relation to the role of individual differences. In other words, instead of positioning individual personality traits in terms of the overall frequency and tendency to experience chills with music, the focus should be on how individual differences relate to variations in the chills experiences, what styles of music are most effective, and what features appear to be potent in eliciting the response. One immediate gap in the literature is the lack of work linking musical chills to musical preferences, and given the relationship between personality and preferences (Rentfrow & Gosling, 2003), this could be an initial opportunity to extend and develop individual differences in relation to distinct musical chills and the styles of music linked to chills for different listeners. Furthermore, it would be pertinent to extend the correlations between individual differences and chills to other domains besides music, such as film, images and poetry, to assess whether some of the inconsistencies in existing research may be derived from the stimuli utilised; these variations, as discussed earlier, might be explained by the distinct musical chills framework and predictions.

9.6.4 Corpus Analysis

A final avenue for extending research into musical chills is to develop a large-scale corpus of chills music, with attributable regions of interest (i.e. chills sections) for each piece, with which music analysis or music information retrieval methods may be carried out. Whilst this work would be correlational in nature, there would be significant value in carrying out a larger scale correlational approach, perhaps at the level of psychoacoustic parameters in chills music, for musical chills research; this would address the fact that musical stimuli samples utilised are small and often not representative of contemporary listening habits and engagements. Across all five studies in this project, participants were at some point asked to provide several selections of music that consistently elicit chills; this has resulted in a relatively small corpus of over 600 pieces of music, which after curation will be made publicly available for future use and additions from researchers in the field of musical chills. The approaches to working with this corpus are numerous and could incorporate a great deal of interdisciplinary collaboration across researchers, such as those with specialised skills in formal music analysis and those with expertise in psychoacoustic feature-extraction, probabilistic modelling and machine learning.

9.7 Conclusions

To conclude the current research project on musical chills experiences, three main aims and research questions were established, based on substantial limitations in the existing literature on the topic; the first aim was to develop a basic understanding of the emotional characteristics of chills, and extending the knowledge of associations between chills and musical features and listening situations; the second aim was to develop and test a causal manipulation approach to musical chills, to progress from the correlational research on the phenomenon, and establish an experimental foundation for testing theories of chills; the final aim was to explore and assess the psychological construct of chills, and test whether chills reflect a unitary indicator of peak pleasure as suggested by neuroimaging perspectives, or instead refer to several distinguishable experiences, distinct based on underlying psychological processes, subjective feeling and psychophysiological response. The current dissertation achieved these three principal aims, culminating in the proposition of a preliminary, speculative, distinct musical chills framework, distinguishing between vigilance chills and social chills in a musical context. With this framework, there are several implications for the interpretation of existing research, and multiple avenues for future work on the topic; there are also numerous limitations with the ideas presented here, and it is important to reiterate that this project only designates the beginning of serious causal research into the musical chills phenomenon.

It is hoped that this preliminary framework or structure for understanding musical chills experiences will be impactful for future research, and the considerations echoed throughout this dissertation be utilised and referred to when contextualising and interpreting results from existing and future work. These theoretical and evidence-based developments also have impact for broader music and emotion work, and chills may be a useful ‘case study’ of sorts to assess the underlying mechanisms of music and emotion in an exaggerated form. Finally, it is hoped that this work finds impact across disciplines within music, such as musicology, ethnomusicology, popular music studies and sociology; there is a great deal of underrepresentation in music and emotion work overall, and regarding musical chills there are promising avenues for continuing research, such as cross-cultural work, better capturing and understanding contemporary listening experiences, and understanding the role of music in diverse circumstances such as religious events.

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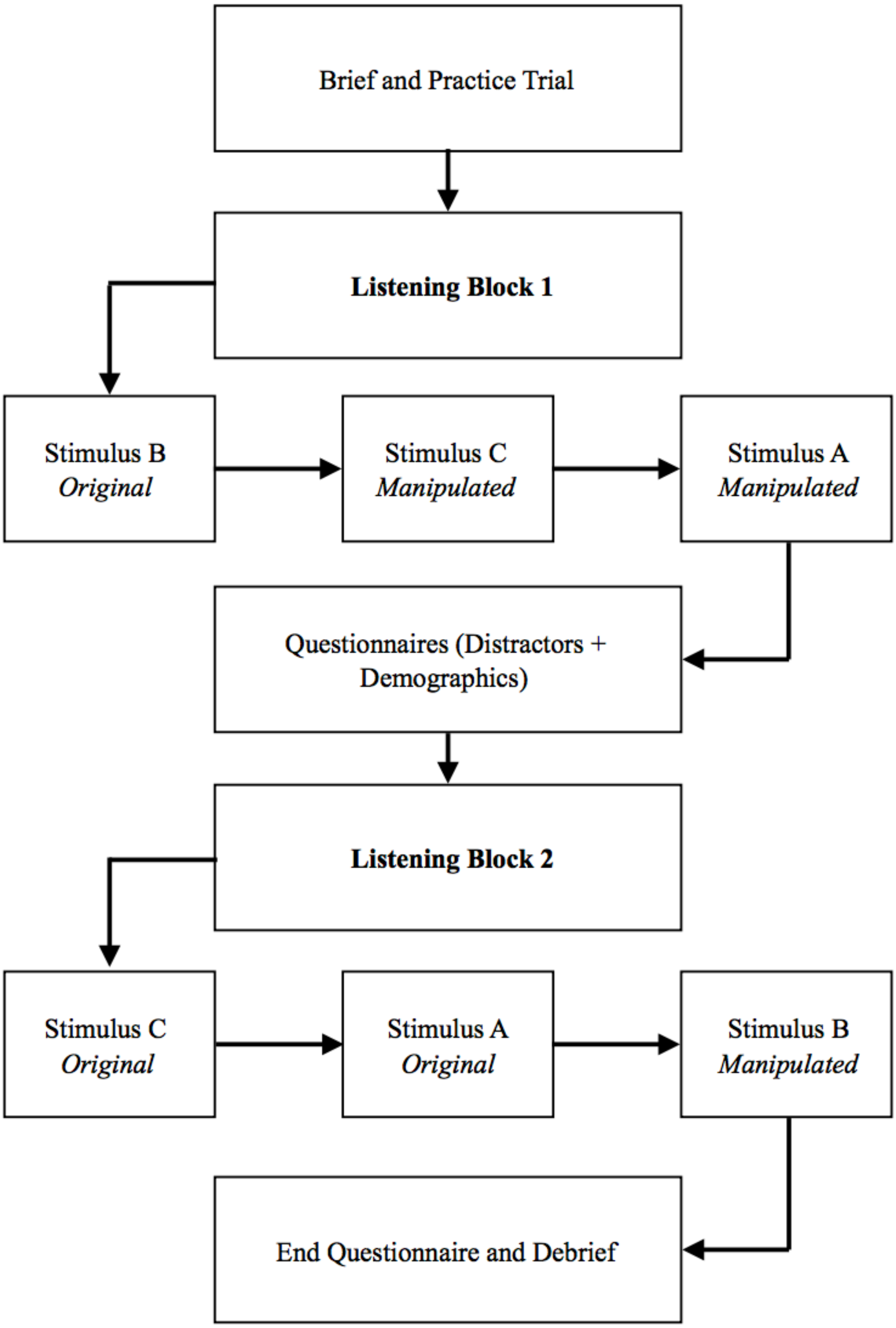
Appendix

Appendix 1: Descriptive Statistics of the Participant Sample for Chapter 5

Descriptives	Sub-Scales	Study Means (SD)	Norm Means
Age		25.20 (5.96)	NA
Openness		5.19 (0.87)	3.89 (0.68)
Musical Sophistication	*Active Engagement*	10.50 (3.55)	9.22 (2.30)
	Musical Training	9.37 (4.83)	7.57 (3.26)
	Emotion	11.25 (2.57)	11.55 (1.68)
STOMP	*Reflective and Complex*	4.69 (1.18)	3.87(1.49)
	Intense and Rebellious	4.68 (1.60)	5.00 (1.46)
	Energetic and Rhythmic	4.00 (1.33)	3.99 (1.51)
	Upbeat and Conventional	4.13 (1.16)	3.74 (1.28)

Appendix 2: Procedural Outline for the Study in Chapter 5



Appendix 3: Descriptive Statistics from the Study in Chapter 6

Descriptive Statistics for the Participant Sample (N = 40)

Variable	**Subscales**	**Mean**	**SD**	**Min**	**Max**
Age		28.51	8.36	19	52
Trait Empathy		63.70	7.34	50	79
	Empathic Concern	13.18	2.95	7	20
	Perspective Taking	15.05	3.30	8	24
	Fantasy	14.68	3.87	7	22
	Emotional Distress	20.16	3.30	12	27
Behavioural Inhibition		12.52	1.44	10	16
Behavioural Activation		22.08	2.99	16	27
	Reward Responsiveness	7.58	1.78	5	11
	Drive	7.50	1.15	5	10
	Fun Seeking	6.74	1.40	4	9

Descriptive Statistics for the Subjective Feeling Data Across conditions for Glósóli and Ancestral (scale ranges are 1-7)

Descriptor	**Glósóli Mean (SD)**	**Ancestral Mean (SD)**
Enjoyment	3.59 (1.04)	3.29 (1.30)
Agitated	1.96 (1.26)	1.84 (1.17)
Joy	3.23 (1.58)	3.36 (1.70)
Energy	3.28 (1.55)	3.30 (1.56)
Affection	2.78 (1.48)	2.86 (1.51)
Moved	3.17 (1.44)	3.49 (1.80)
Sad	1.86 (1.25)	2.15 (1.32)
Sentimental	2.83 (1.42)	2.84 (1.50)
Nervous	1.72 (1.10)	1.64 (1.12)
Tender	2.42 (1.35)	2.29 (1.32)
Nostalgia	2.56 (1.62)	2.82 (1.70)

Descriptive Statistics for the Physical Activity Data Across Pieces (frequency data)

Descriptor	**Glósóli Total Reports**	**Ancestral Total Reports**
Coldness	33	32
Warmth	18	16
Lump in the Throat	4	9
Tears	1	3
Smiling	35	29
Frowning	1	9

Appendix 4: Descriptive Statistics and Stimulus Details for the Study in Chapter 7

Descriptive Statistics for the Participant Sample; values in parentheses denote standard deviations.

Variable	Male	Female	Transgender / Other / Unreported	**Overall**
Sample Size	52	114	13	179
Mean Age	32.31 (10.05)	30.37 (11.89)	28.83 (6.46)	30.91 (11.20)
Overall Chills	88	238	18	344
Mean Chills	1.69	2.08	1.38	1.71
Image Chills	17	45	4	66
Video Chills	25	69	5	99
MV Chills	16	52	4	72
Text Chills	15	34	1	50
Music Chills	15	38	4	57
IRI Mean	87.20 (11.72)	90.04 (8.88)	94.16 (8.32)	89.35 (9.86)
Fantasy	22 (4.95)	23.01 (3.53)	25.33 (2.80)	22.79 (3.97)
Empathic Concern	21.60 (3.45)	22.21 (2.48)	23.33 (1.50)	22.07 (2.79)
Perspective Taking	22.88 (4.29)	23.53 (3.02)	24.66 (4.63)	23.37 (3.49)
Personal Distress	20.13 (4.07)	21.35 (3.53)	20.83 (3.31)	20.97 (3.72)

Number of chills responses to the fifteen multimedia stimuli, ordered by relative efficacy.

Stimulus	**Modality**	**Thematic Category**	**Chills Frequency**	**Source**
Funeral Haka	Video	*Communion*	**34**	https://www.youtube.com/watch?v=M6Qtc_zlGhc
Dog Reunion	Video	*Love and Gratitude*	**33**	http://i.imgur.com/IEHbOVc.gifv
Scientists Celebrate	Video	*Communion*	**32**	https://www.youtube.com/watch?v=igEWYbnoHc4
Jupiter	Music	*Solo Voice or Instrument*	**31**	Taken from album '*The Planets / Suite de Ballet, op. 10*' (Released 1991 under Naxos) Catalogue number = 8.550193 Barcode = 4891030501935 Musicbrainz Identifier = 2e5015c8-c0a1-4b50-aa68-2dad4529c972
Queen Singalong	Music Video	*Communion*	**28**	https://www.youtube.com/watch?v =cZnBNuqqz5g&feature=youtu.be
Ave Maria	Music Video	*Solo Voice or Instrument*	**27**	https://www.youtube.com/watch?v=a04O1RmCS8M
War Veteran	Image	*Distress and Support*	**26**	https://imgur.com/MyxObav
Innocent Man	Image	*Distress and Support*	**21**	https://imgur.com/3tMeMSu

Father Pride	Text	*Love and Gratitude*	**21**	https://www.reddit.com/r/Frisson/comments/5kd1ks/text_a_bit_unconventional_for_this_sub_but_one_of/
Gorilla	Image	*Distress and Support*	**19**	https://i.imgur.com/Y01CTLO.jpg
Professor Quote	Text	*Love and Gratitude*	**19**	http://i.imgur.com/ZAgoWG6.jpg
Swiss Band	Music Video	*Communion*	**17**	https://www.youtube.com/watch?v=IEng60LouQo&feature=youtu.be
Ancestral	Music	*Solo Voice or Instrument*	**14**	Taken from album '*Hand. Cannot. Erase.*' (Released 2015 under Kscope) Catalogue number = KSCOPE316 Barcode = 802644831671 Musicbrainz Identifier = 0cfad70c-4fa9-43c2-918e-eb638f0dd597
Glósóli	Music	*NA*	**12**	Taken from album '*Takk...*' (Released 2009 under EMI Music Australia) Catalogue number = 695 4682 Barcode = 5099969546822 Musicbrainz Identifier = d79744e1-a616-3e75-844d-9d83ad5da6a3
Recovered Addict	Text	*Love and Gratitude*	**10**	https://www.reddit.com/r/Frisson/comments/52w7xq/text_a_thank_you_letter_from_a_heroin_addict/

Appendix 5: Descriptive Statistics for the Study in Chapter 8

Variable	Male	Female	**Overall**
Sample Size	17	27	44
Mean Age	32.31 (10.05)	30.37 (11.89)	27.56 (7.44)
Overall Chills	220	472	692
Mean Chills	3.23	4.45	3.97
EQ	40.58 (8.23)	47.83 (13.24)	45 (12.05)
SQ-R	70.17 (16.44)	55.36 (18.08)	61.15 (18.86)

Appendix 6: Animation Details and Sources for the Study in Chapter 8

The Oceanmaker (Directed and edited by Lucas Martell, Production Co.: Mighty Coconut, Martell Animation, Ponysound). Released 2014. YouTube URL: https://www.youtube.com/watch?v=J2J4eareIIg

The OceanMaker is a short, 11-minute animated film (edited down to roughly 6 minutes for the purposes of **Chapter 8,** and paired with *Glósóli* by Sigur Rós), set in a scorched land seemingly short on water. Through desperation, pilots fly through rare rain clouds to collect and harvest water for several purposes, some selfish and other heroic. The main protagonist, attempting to develop a 'Rain Maker' machine, engages in a dogfight with other antagonist planes over a rain cloud. Over the course of the fight, the rain cloud grows larger, eventually becoming a storm cloud. At this moment however, the antagonist planes are shot out of the sky, by a much larger incoming plane, aiming to harvest the full storm cloud for itself. The protagonist pilot eventually engages in a risky dogfight with this large plane, and is eventually badly injured (at this point, the chills section from Glósóli begins). Upon realising that they will not survive the fight, the protagonist decides to fly headfirst into the oncoming large plane, as an act of self-sacrifice for the greater good. As the planes collide, all pilots are killed, but the harvested rainwater is released from the collision, and rains down on the land and inhabitants, potentially saving their world. The final scenes of the animation, amidst a dark rain storm, shows the schematics for the 'Rain Maker' land in front of a small girl, who whilst in awe of the rain storm, appears to be inspired to continue the development of this technology.

This animation represents a prototypically moving scenario linked to the elicitation of chills, specifically the blending of negative foreground events (self-sacrifice) with positive background events and consequences (saving others, sacrifice for the greater good); see Wassiliwizky et al. (2015).

Storks (Directed by Nicholas Stoller and Doug Sweetland, Production Co.: Warner Bros. Animation, Warner animation Group, RatPac-Dune Entertainment). Released 2016. YouTube URL for clip used: https://www.youtube.com/watch?v=DtPbGfn6uug

Storks is originally a feature-length animated movie (a shorter 3-minute clip from the conclusion of the movie was utilised from YouTube, and edited down to roughly 2 minutes for the purposes of Chapter 8, paired with *Behind the Door* by Nobuo Uematsu). The short clip from the film that was used depicts the old myth of Storks delivering babies to waiting parents. The beginning sees all Storks fly to many different locations, delivering babies to happy and adoring parents. Following this short opening, the clip then shows a family nervously and anxiously waiting for something, as if unsure that their baby would ever arrive. However, the son of the family sees a Stork fly past, and the family become excited and await at the front door of the house. As the Stork lands in front of them, replacing a loose bundle of sheets with the family, they unveil the smiling baby they had been waiting for (at this point the music moves through a dynamic climax and crescendo). As the family are united, the Stork begins to say goodbye, indicating a meaningful relationship between bird and baby; at this point the baby reaches out to touch the Stork, and the bird imagines the significant life events in the baby's life that it will miss, but appears comforted in the end by the touch and relationship they appear to have built previously. The Stork flies away, and the end of the clip shows the family waving goodbye.

This animation also depicts a prototypical moving scenario linked to chills experiences, but in contrast the *The Oceanmaker*, presents a positive foreground event (reunion of family) with a negative background event (separation of Stork and baby, implied separation of family and baby); see Wassiliwizky et al. (2015).

Appendix 7: Self-Report Instruments Utilised in Chapter 8

AWE-S Instrument (Yaden et al., 2019)

Summary: This self-report instrument is comprised of a six-factor structure, with the factors labelled *time perception*, *self-diminishment, connectedness, perceived vastness, physical sensations,* and *need for accommodation.* For the purposes of the study in **Chapter 8**, the three factors of perceived vastness, physical sensations, and need for accommodation were utilised; the self-report scales were all 1-7 Likert-type, as follows:

Apart from any chills, how much did you experience any of the following sensations (1 = not at all, 7 – very much):

Jaw dropping

Gasping

Widening of the eyes

Please rate your listening experience on the following scales of 1-7 (1 being not at all, 7 being very much):

I felt I was in the presence of something grand

I experienced something greater than myself

I felt in the presence of greatness

I perceived something that was much larger than me

I perceived vastness

I felt challenged to mentally process what I was experiencing

I found it hard to comprehend the experience in full

I felt challenged to understand the experience

I struggled to take in all that I was experiencing at once

I tried to understand the magnitude of what I was experiencing

KAMMUS-2 Instrument (Zickfeld et al., 2018)

Summary: This self-report instrument is comprised of a five-factors structure, encapsulating *physical sensations, feelings of social connection, motivation for social connection, positive valence,* and *being moved.* For the study in Chapter 8, physical sensations were targeted (beyond the prototypical chills sensations of goosebumps, shivers and tingling), alongside feelings and motivations for social connection. All ratings scales utilised were 1-7 Likert-type, as follows:

Apart from any chills, how much did you experience any of the following sensations (1 = not at all, 7 – very much):

Moist eyes

Warmth in the chest

Lump in the throat

Please rate your listening experience on the following scales of 1-7 (1 being not at all, 7 being very much):

I felt an incredible bond

I felt an exceptional sense of closeness appear

I felt a unique kind of love spring up

I felt an extraordinary feeling of welcoming or being welcomed

I felt like telling someone how much I care about them

I wanted to hug someone

I wanted to do something extra-nice for someone

I felt more strongly committed to a relationship